An exploration of the influence of activity and occupation on recovery from a surgically treated distal radius fracture

Julie M. Collis

2022

A thesis submitted to Auckland University of Technology in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD)

School of Clinical Sciences

A prose sentence which touches like a branding iron is good. A sentence which keeps its feet clean from beginning to end is good. A sentence which, travelling, looks out of portholes as far as horizons and beyond is good. A sentence which goes to sleep is good, if the season is winter; bad, if it is early spring. A sentence which stumbles on useless objects instead of on buried treasure is bad, and worse if it illuminates useless objects with artificial light, but good if it casts a unique radiance upon them. A word which is exciting to look at and say and which doesn't slop its meaning over the side is good; a word which comes up sparkling from the well is good; a word which clusters like last year's bee around last year's flower is bad if the flower is already dead, but good if the flower is surviving, beautiful, and alone in a place where flowers have not been known to grow and where bees never swarmed before nor gathered nectar.

-Janet Frame, *Living in the Maniototo, 1979*

Abstract

A distal radius fracture is a common injury of the upper limb. Distal radius fractures can result in wrist stiffness, sensorimotor impairment, and activity limitations that can persist for weeks or months following injury. For fractures that are treated surgically, it is common practice to commence mobilisation within two weeks to restore movement and prevent such sequelae. Traditional postoperative rehabilitation predominantly relies on range of motion exercises to restore wrist and hand movement. Hand therapists may also advocate for the performance of daily activities, but purposeful activities are not a routine component of early mobilisation regimes. Recent literature challenges hand therapists to increase the use of activity and occupation-based approaches, however, understandings of how activities and occupation are currently used and how they bring about change is limited.

This research aimed to explore how daily activities and occupation influences recovery after surgical treatment of distal radius fractures. The intent of the research is to understand the mechanisms of how occupation brings about improvements and to inform the development of occupation-based interventions. The research uses a mixed methodology design informed by a critical realist paradigm and is presented in manuscript format. Three published papers and a manuscript currently under review are presented. Introductory, intervening, and concluding chapters are included to tie the manuscripts together into a cohesive narrative for this doctoral work.

I begin by introducing the philosophical underpinnings for this research, the context of distal radius fractures, and the use of activity and occupation-based approaches. Two systematic reviews are then presented. The first review (study I) evaluated studies that examined the influence of purposeful activities on upper extremity motor performance. Results suggested that upper extremity movement quantity and quality were enhanced when performed during purposeful conditions. The second review (study II) evaluated studies that compared early and delayed mobilisation following volar plating of distal radius fractures. The review explored how daily activities are recommended in early mobilisation

regimes and evaluated the efficacy and safety of early versus late mobilisation. Results showed that performing daily activities was commonly recommended as part of early mobilisation and suggested better functional and biomechanical outcomes for people who commence mobilisation prior to two weeks. The two systematic reviews highlighted the need for research into the specific mechanisms of action of purposeful activities in early rehabilitation.

Primary research was then undertaken. Patient perspectives on the influence of activity and occupation on recovery from a surgically repaired distal radius fracture were explored in an Interpretive Description qualitative study (study III). A randomised crossover study was conducted (study IV) in which wrist movement during purposeful activities was evaluated using electrogoniometry and compared with movement during active range of motion exercises. Chapter ten presents a descriptive synthesis of researcher observations and reflections. Key findings from each of the studies are then collectively drawn together in an integrated discussion chapter.

Findings suggest that activities and occupation are highly influential in facilitating the recovery of movement and function in the early weeks after surgical treatment of a distal radius fracture. Performing purposeful activities may facilitate recovery by eliciting substantial active movement of the wrist, and by building psychosocial resources. Study III revealed that purposeful activities are a powerful potentiator of motivation, wellbeing, optimism, restoring body schema and habituating the person’s wrist to movement. Study IV provided novel data demonstrating that significantly greater volumes of movement are produced by performing purposeful activities, when compared to standard range of motion (ROM) exercises, and that purposeful activities elicit available end range of movement equally as well as ROM exercises.

Taken, together my research challenges traditional postoperative management approaches and suggests the substantial potential of activity and occupation as a rehabilitative strategy. Based on my research findings, I propose an occupation-based postoperative approach that harnesses the unique remediating mechanisms of activity and occupation.

Contents

Attestation of Authorship

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

10/01/202

Co-authored Works

Chapter 4 Collis, J. M., Signal, N., Mayland, E., & Wright-St Clair, V. A. (2020). Influence of purposeful activities on upper extremity motor performance: A systematic review. OTJR: Occupation, Participation and Health, 40, 223-234. https://doi.org/10.1177/1539449220912187	**Collis (80%),** conceived and registered the study, conducted the investigation and the data analysis, wrote the manuscript, responded to journal reviewer feedback. **Signal (6%),** conceived the study, provided supervision of the study (oversight and leadership responsibility), collaborated on analysis of the data, provided feedback on manuscript drafts. **Mayland (8%),** provided supervision of data collection and analysis, conducted cross-scoring of quality evaluation, provided feedback on manuscript drafts **Wright-St Clair (6%),** conceived the study, conducted screening of full-texts, provided supervision of the study (oversight and leadership responsibility), collaborated on analysis of the data, provided feedback on manuscript drafts.
Chapter 5 Collis, J. M., Signal, N., Mayland, E., & Wright-St Clair, V. (2020). A systematic review of how daily activities and exercises are recommended following volar plating of distal radius fractures and the efficacy and safety of early versus late mobilisation. Hand Therapy, 25, 139-151. https://doi.org/10.1177/1758998320967032	**Collis (80%),** conceived the study, registered the study, conducted the investigation and the data analysis, drafted the manuscript, responded to journal reviewer feedback. **Signal (8%),** conceived the study, provided supervision of the study (oversight and leadership responsibility), conducted quality evaluation scoring, collaborated on analysis of the data, provided feedback on manuscript drafts. **Mayland (6%),** conceived the study, provided supervision of data collection and analysis, provided feedback on manuscript drafts. **Wright-St Clair (6%),** conceived the study, provided supervision of the study (oversight and leadership responsibility), collaborated on analysis of the data, provided feedback on manuscript drafts.
Chapter 7 Collis, J. M., Mayland, E. C., Wright-St Clair, V., & Signal, N. (2021). "The more I do, the more I can do": perspectives on how performing daily activities and occupations influences recovery after surgical repair of a distal radius fracture. Disability and Rehabilitation, 1-10. https://doi.org/10.1080/09638288.2021.1936219	**Collis (80%),** conceived the study, acquired the funding, registered the trial, wrote, and submitted the ethics and localities applications, conducted the investigation, drafted the manuscript, responded to journal reviewer feedback. **Mayland (6%),** conceived the study, provided supervision of data collection and analysis, provided feedback on manuscript drafts. **Wright St-Clair (6%), and Signal (8%),** conceived the study, provided supervision of the study (oversight and leadership responsibility), collaborated on analysis of the data, provided feedback on manuscript drafts.

Chapter 9 (Manuscript under review) An evaluation of wrist and forearm movement during purposeful activities and range of movement exercises after surgical repair of distal radius fractures: A randomised crossover study. Collis, J. M., Mayland, E. C., Wright-St Clair, V., Rashid, U., Kayes, N., & Signal, N.	**Collis (80%),** conceived the study, acquired funding, ordered, and tested the equipment, registered the trial, wrote, and submitted the ethics and localities applications, conducted the investigation, collaborated with Rashid on the statistical analyses, oversaw data curation, drafted the manuscript, responded to journal reviewer feedback. **Mayland (4%),** conceived the study, provided supervision of data collection and analysis, collaborated on analysis of the data, provided feedback on manuscript drafts. **Wright St-Clair (3%),** conceived the study, approved the final manuscript. **Rashid (4%),** advised on aspects of study design, conducted statistical analysis of the data, collaborated on data interpretation, provided feedback on manuscript drafts. **Kayes (3%),** collaborated on analysis of the data, provided feedback on manuscript drafts. **Signal (6%),** conceived the study, provided supervision of the study (oversight and leadership responsibility), collaborated on analysis of the data, provided feedback on manuscript drafts.

Julie Collis	Associate Professor Nada Signal	Professor Nicola Kayes
Professor Valerie Wright-St Clair	Doctor Elizabeth Mayland	Doctor Usman Rashid

List of Figures

List of Tables

Acknowledgements

This thesis represents the mahi of the past few years and could not have been achieved without the support of many people.

My deep gratitude goes to my supervisors Nada Signal, Valerie Wright-St Clair, Elizabeth Mayland, and Nicola Kayes. Nada, thank you for your constant belief in my research and for the astute guidance you've provided throughout my PhD. You encouraged me to expand my thinking, strive for excellence, and find my own voice in the research. I have learnt a great deal from you. Val, for getting me started on the PhD journey and for imparting your wisdom and expertise about research methods. Beth, for your insights and probing questions that constantly refined my work. You helped me to dig deep. Nic, thank you for coming in towards the end of my doctoral work. Many of the perspectives that shaped my final document would not be there without your input.

To my participants. It blew me away that so many people were willing to take part in a study having just had surgery for a wrist fracture. It speaks to me of the curiosity and generosity of human beings. Thank-you.

I am thankful for my PhD being supported by an AUT Vice-Chancellors scholarship. I am also grateful for research grants received from Counties Manukau Health, Hand Therapy New Zealand - Ringaromi Aotearoa, and Occupational Therapy New Zealand - Whakaora Ngangahau Aotearoa.

Thanks to everyone in the Research Innovation Centre team. You gave me a place of belonging and taught me a lot about research. A special thanks to Kate Charlesworth and Usman Rashid for your work with my research.

To all the hand therapy team at the Manukau Super Clinic. You've been behind me all the way, enthusiastically supporting my research. Alieke, without your leadership and support, research would not happen in our team. You make excellence possible. Amy, thanks for helping me with figuring out the electrogoniometers, you've no idea how much I valued your help. Shirley, your thoughtful attention to reading sections of my work and for the many discussion we've had about my PhD (and about life) have been like gold.

To Heidi, always there, cheering me on. For the many messages that would pop up at just the right time, for hugs (when they were allowed) and for the walks and talks. Your unwavering belief in my research got me through more than a couple of hard days. Thank you. Now it's time to get back to creating!

To my sister Sue, right from the beginning you've been interested in the minutiae of my research and my PhD journey. You've understood what it's taken to get here and what is gained through a PhD. Your deep interest and understanding means the world to me.

To Jesse, Todd, and Anna. You are amazing human beings and you each continue to astonish me with your tenacity, uniqueness, and thoughtfulness. Thank you for supporting me throughout my PhD, for the knowledge you each shared with me, and for just being truly wonderful.

Bill, we have shared more than a few adventures together. One of the best and unexpected has been our academic journey. We have individually and together challenged our thinking and expanded our perspectives on life and our professional spheres. Thank you for the many practical ways you've supported me throughout my PhD, but most of all for the kōrero and the togetherness of our knowledge sharing and learning. Your love has centred and sustained me.

Glossary of Terms

Activity	Actions or sets of tasks that hold meaning, relevance, and perceived utility. Activities when grouped together make up occupations (American Occupational Therapy Association, 2020).
Activity limitations	Difficulties in executing activities (https://www.who.int/classifications/icf/training/icfbeginnersguide.pdf)
AO classification	A classification system for distal radius fractures. Classifies fractures according to articular involvement. Type A are extra-articular, Type B denotes partial disruption of the articular surface, and Type C are fractures with complete articular involvement (Schneppendahl et al., 2012).
Disability	An umbrella term for impairments, activity limitations and participation restrictions (https://www.who.int/classifications/icf/training/icfbeginnersguide.pdf).
Distal radius fracture	A fracture to the distal end of the radius, typically resulting from a low energy fall onto an outstretched hand (MacIntyre & Dewan, 2016).
Early mobilisation	Commencing movement of the wrist through exercises and activities within two weeks of surgery (Inclan & Dy, 2021).
Hand therapist	An occupational therapist or physiotherapist who has specialised in the diagnosis and management of conditions of upper extremity conditions resulting from trauma, disease, and congenital deformity (https://www.handtherapy.org.nz/)
Impairment	Problems in body function or structure (https://www.who.int/classifications/icf/training/icfbeginnersguide.pdf)
Mixed methodology	A research approach that uses both qualitative and quantitative methods in the quest for knowledge (Timans et al., 2019).
Mixed methods	A single study that employs both quantitative and qualitative methods (Tariq & Woodman, 2013)
Motor performance	The observable production of a voluntary action or motor skill (Schmidt & Wrisberg, 2008, p. 11)
Occupation	The broad categories of daily life engagements by which people occupy themselves: daily living activities, rest, education, work, leisure, and social participation (American Occupational Therapy Association, 2020). Occupation assumes meaning, purpose, intentional engagement, and that occupation is contextualised within daily life (American Occupational Therapy Association, 2020).
Occupation-based intervention	A broad term to define an intervention that uses valued activities or occupation for the purpose of remediating impairment. Occupation is specified as the therapeutic agent of change (Fisher, 2014; Hinojosa & Blount, 2014b).

Participation restrictions	Problems an individual may experience in being involved in life situations (https://www.who.int/classifications/icf/training/icfbeginnersguide.pdf).
Purposeful activity	Activities that a person actively and intentionally performs to achieve a specified therapeutic goal (biomechanical or occupational). The activities always hold meaning, relevance, and perceived utility. (American Occupational Therapy Association, 2020; Hinojosa & Blount, 2014b).
Range of motion (ROM)	The range of motion available at a synovial joint (Mancinelli & Davis, 2006).
Range of motion exercise	An exercise performed to improve range of motion at a specific joint (Mancinelli & Davis, 2006).
Reflexive thematic analysis	An umbrella term for analysing qualitative data aimed at identifying themes (patterns of meaning) across qualitative datasets. Reflexive thematic analysis may use differing theoretical perspectives but is characterised by researcher reflexivity, emphasizing the active role of the researcher in the knowledge production process (Braun et al., 2019).
Sensorimotor retraining	Educates people to improve attention to sensory cues so that the brain can produce efficient motor commands. People are also educated on the correct interpretation of sensory feedback and efficient control of the hand (Valdes et al., 2014).
Sensorimotor system	A component of the motor control system that integrates sensory and neuromuscular processes to provide the functions of coordinated movement and dynamic stability. Specific functions include the ability to detect joint position sense, and perception of force (Karagiannopoulos & Michlovitz, 2016).
Stiffness	Joint stiffness refers to a limitation of joint motion caused by tightness or shortening of soft tissues surrounding joints (Glasgow et al., 2010).
Volar plate	Volar locking plates are metal plates anatomically contoured to fit the volar surface of the distal radius, they are fixed to the bone surgically to correct the and maintain the position of the distal radius after a fracture (Loisel et al., 2018; Quadlbauer et al., 2017).
Wellbeing	A state of overall contentment with one's physical and mental health, self-esteem and sense of belonging, social opportunities, financial security, and ability to engage in meaningful occupation (Hammell, 2010).

List of Appendices

List of Abbreviations

CMDHB	Counties Manukau District Health Board
CRPS	Complex Regional Pain Syndrome
DRUJ	Distal Radioulnar Joint
ID	Interpretive Description
MRC	Medical Research Council
N	Newtons
ORIF	Open Reduction Internal Fixation
RCT	Randomised Controlled Trial
ROM	Range of Motion
RQ	Research Question

Chapter 1 Introduction

1.1 Context of the thesis

A fracture to the distal radius is a common upper limb injury and for some people causes long-term disability. Surgical treatment of distal radius fractures, as opposed to cast immobilisation, is becoming increasingly common, particularly for more complex fracture types (Loisel et al., 2018). After surgery, hand therapists are often involved in the rehabilitation of this injury. The aims of therapy are to restore range of motion (ROM), strength and function to the affected limb (Kooner & Grewal, 2021). Most people make a satisfactory recovery after a surgically repaired distal radius fracture but some experience persistent joint stiffness, pain, sensorimotor impairments, and difficulties performing activities of everyday living (MacFarlane et al., 2015). Following surgery, it is now becoming common practice to begin early mobilisation of the wrist, usually within two weeks of surgery. The purported benefits of early mobilisation include improved ROM of the affected joints, early return to functional use, a low incidence of complex regional pain syndrome, and high patient satisfaction (Loisel et al., 2015; Quadlbauer et al., 2020). The role of a hand therapist during the first six weeks of rehabilitation is to promote movement and functional use of the wrist while balancing the requirements of bone healing (Naughton & Algar, 2021).

Hand therapists use a variety of treatment strategies to restore movement and function to the injured limb. In the early weeks of therapy this traditionally focuses on exercise repetitions with intervening protection of the fracture in a wrist brace or customised splint (Naughton & Algar, 2021). Wrist motion can also be promoted through specified performance of daily activities. However, the use of activities and occupation as a rehabilitative strategy appears to be under-described and under-utilised as part of early surgical distal radius fracture rehabilitation. The terms pertaining to activity and occupation are defined in 3.3.1, but by way of introduction, occupation refers to the various life activities in which people engage during the course of their day to day life (American Occupational Therapy Association, 2020). They are broad categories that include activities of daily living, rest and sleep, education, work, play, leisure, and social participation. The construct of occupation assumes that those occupations have meaning to the person performing them, involve active engagement, are valued for their utility, and occur in the context of environment and life roles (Melchert-McKearnan et al., 2000; Molineux, 2010). Activities are smaller actions or sets of tasks that occupations are constructed from; they are the components of occupations (American Occupational Therapy Association, 2020; Polatajko et al., 2004),

Occupation can be used as a therapeutic tool to bring about improvements following injury or a health event (American Occupational Therapy Association, 2020). Using activities and occupation therapeutically may have some advantages over exercise repetitions, such as eliciting functional planes of movement, mitigation of pain through distraction, enhancing motivation in therapy, and delivering higher doses of movement than rote exercise approaches (Hoppe et al., 2008; Robinson et al., 2016; Weinstock-Zlotnick & Mehta, 2018). Despite such purported advantages there are gaps in our understandings of how activities and occupation influence recovery from an upper limb injury. It is not fully understood how activity and occupation influences motor performance in people with an upper limb injury, recommendations on the safe use of activity in early surgical distal radius fracture rehabilitation are not well defined, patient perspectives on the influence of daily activities on recovery after surgery have not been fully explored and mechanistic understandings of how activities influence wrist movement are unknown.

1.1.1 Aims and objectives

The aim of the research is to explore the ways that daily activities and occupations influence recovery after surgical treatment of distal radius fracture. The research is exploratory in nature, investigating concepts that have not been comprehensively described in the literature. The intent of this doctoral work is to understand how occupation operates to bring about improvements and inform the development of occupation-based interventions. The research uses a mixed-methodology design underpinned by a critical realist paradigm.

1.2 Research questions

The overarching research question (RQ) is: how does activity and occupation influence recovery after a surgically treated distal radius fracture?

The specific questions are:

1. Does performance of purposeful activities and occupation influence upper extremity motor performance differentially from exercises or non-purposeful movement in healthy and musculoskeletal injury populations (RQ1)?
2. How is activity recommended following surgical treatment of distal radius fractures and what is the efficacy and safety of early versus delayed mobilisation (RQ2)?
3. What are the experiences and perceptions of patients on how participation in daily activities and occupations influence recovery after surgery for distal radius fracture (RQ3)?
4. Does performance of daily activities result in greater quantity of motion than active range of motion exercises following surgical treatment of distal radius fracture (RQ4)?

1.3 Thesis structure

The thesis is structured around four phases. Each phase is intended to explore a different aspect of the influence of activity and occupation on recovery from a surgically repaired distal radius fracture.

The remainder of this chapter gives an overview of each phase and the corresponding thesis structure. Chapter 2 then presents the philosophical and methodological frameworks of the thesis and Chapter 3 discusses concepts of distal radius fractures and occupation that form the background to the thesis.

1.3.1 Phase one

The research starts by establishing the positionality of occupation in the rehabilitation of a musculoskeletal injury. Two reviews were undertaken using a standard systematic review approach and were published in rehabilitation journals. The first systematic review, study I (Chapter 4) aimed to determine whether occupation elicits movement differentially from exercise repetitions after musculoskeletal injury, addressing RQ1. Study II, Chapter 5 then narrows the focus towards distal radius fracture rehabilitation by evaluating how activity is recommended following surgical treatment (RQ2). The results of these systematic reviews contributed to a deepening understanding of the influence of occupation on recovery from injury, and informed the primary research undertaken in phases two and three.

1.3.2 Phase two

Phase two is an Interpretive Description qualitative study (study III), that addressed RQ3. The study explored patient perspectives and is presented in Chapter 6 and Chapter 7 . Chapter 6 describes the rationale and procedures used in the study and Chapter 7 presents the published article for that study. The study conducted exploratory interviews with 21 adults with a surgically treated distal radius fracture. The data were analysed using reflexive thematic analysis. The rationale for conducting the Interpretive Description study first was because little had been written about the influence of occupation on the recovery from surgical treatment of a distal radius fracture. It was not known whether occupation would be viewed as a remediator of recovery or how performing daily activities was experienced. I wanted first-hand accounts from people immersed in the rehabilitation journey before embarking on a quantitative study. An additional objective of the qualitative study was to identify activities that could be tested during the motion analysis study in phase three.

1.3.3 Phase three

The subsequent two chapters (Chapter 8 and Chapter 9) represent phase three of the research. In this phase, the research shifts from patient perspective to that of independent, objective measurement. A motion analysis study, (study IV), was conducted to address RQ4 and is presented in the form of a manuscript submitted for publication. The study measured and compared motion during performance of daily activities and exercise repetitions, in a randomised crossover study. The study tested the hypothesis that greater or similar quantity of movement is elicited during self-selected activities than standard active ROM exercises. Chapter 10 then presents a synthesis of researcher observations and insights from journaling I undertook during the research. The observations resulted from incidental conversations that occurred during study IV data collection, my reflections of these conversations, and visual inspection of the electrogoniometer and video data. This chapter was important to include because these observations revealed understandings about the mechanisms of purposeful activities not evident in my studies.

1.3.4 Phase four

Armed with knowledge gained from research perspectives during phases one, two and three, the thesis transitions to phase four where the results are synthesised in an integrated discussion (Chapter 11). In this chapter, findings from across the research are integrated into four key points that each highlight a unique contribution of the research. The points are discussed with particular reference to how my research findings can inform clinical practice. An occupation-based rehabilitation approach based on my research findings is then proposed. The approach utilises the unique characteristics and mechanisms of occupation in bringing about improvements in movement and function after a surgically repaired distal radius fracture, complementing traditional exercise-focused rehabilitation. Chapter 11 concludes with a discussion of strengths, limitations, future directions, and a summary of the thesis.

The chapters that contain a published article are presented in the format consistent with the thesis. Figures and tables are numbered consecutively throughout the thesis rather than as they appear in published format. The articles in their published format are appended at the end of the thesis.

1.4 Scope and delimitations

The research in this doctoral work seeks to understand the mechanisms by which activities and occupation influence recovery from a surgically treated distal radius fracture. The intention is to provide knowledge that can inform the future use of purposeful activities and occupation as a rehabilitative strategy. The research is limited to the first stage of developing complex interventions as outlined by the

Medical Research Council (MRC) (Craig et al., 2013). This involves identifying existing evidence to understand what is already known, developing theory to explain the rationale and mechanisms of action of the intervention, and modelling of processes and outcomes. In this research phase one examines evidence via two systematic reviews. Exploring the mechanisms of action of activities and occupation occurs in phases three and four by way of two primary studies. Both studies were conducted in the homes of people with a surgically repaired distal radius fracture. The initial steps of modelling the intervention occurs in phase four where the research findings are synthesised, and an occupation-based rehabilitation approach proposed. The scope of this research does not extend to full development of an intervention nor to investigation or evaluation of the efficacy of a purposeful activity intervention.

Chapter 2 Philosophical underpinnings and methodology

This chapter presents the philosophical perspective of critical realism and methodologic considerations that underpin the research. I will first position myself in the research, describe critical realism and give a rationale for mixed methodology.

2.1 The researcher, who am I?

Positioning oneself as a researcher distinct from clinical, professional, and personal life roles is essential to robust research practice and helps to delineate the researcher role (Thorne, 2016b). In this section I discuss my personal journey towards research, my clinical background, and my interest in the research topic.

At the beginning of this thesis I inserted a quote by Janet Frame from Living in the Maniototo (Frame, 1979). It may be grandiose to claim that a thesis such as this might 'cast a unique radiance on buried treasure', but the quote spoke to me of the usefulness of research. It alludes to the fact that the point of enquiry is to shed light on something, to add new knowledge or to open up new possibilities. The thing that motivated me to undertake doctoral studies was the desire to find out something new, something that was not fully understood. A quote from my pre-suppositions interview, described in Chapter 6 , illustrates these characteristics and helps to position me within the research.

> I guess I'm a curious person. I work with colleagues who are also curious, I mean we're a team that likes to ask questions. We like doing projects, we've done lots of audits of outcomes so there's a culture in our team of evaluating outcomes and critically evaluating our practice. As a person I like to travel, I like to go to new places and find out what makes people tick. When we travel, we go to historical sites and see the past of the people who've been there before, where they've come from and what makes them, you know, who they are as people. In terms of my clinical practice, I'm never just interested in the physiology or the pathology of the disease process. I'm always interested in the person themselves, who they are, what they like to do and how they're adjusting to an injury. What is it that's important, what's been difficult, what can I do as a therapist to help? I guess in our family we've always asked questions and talked about the world and society and the things that are good in the world and the things that are not the way that they should be, what we would like to be better or different in the

> way people are treated and included in society. So those questions have always been important for me.
>
> Julie Collis (paraphrased)

My background as a clinician is occupational therapy. I have practiced in the fields of rheumatology, chronic pain, and mental health. Over the past 14 years my clinical practice has been in hand therapy, primarily in a publicly funded outpatient hand therapy clinic. My postgraduate academic career began when I returned to paid employment after several years at home with young children. I completed my Masters of Health Science in 2011 having conducted a randomised controlled study of the efficacy of night extension splinting following fasciectomy for Dupuytren contracture (Collis et al., 2013). My interest in research continued and I completed a number of quality improvement projects (Collis, 2014, 2018; Collis & Collocott, 2009; Myhr & Collis, 2018).

Mixed-methods research naturally appealed to me. Experiences of human beings cannot be confined to controlled experiments or clinics. An injury is not planned, it happens in an instance and cuts through life like a knife. Rehabilitation also happens in the messiness of life. It happens while you are planning an overseas trip, while you are cooking dinner, and while struggling to do your hair. After injury and surgery people must reassemble their daily lives. Doing life is immutable and I wanted to find out how the doing of everyday daily life could be harnessed to facilitate recovery. I knew that quantitative data would be important for providing evidence to support practice change but to obtain a comprehensive understanding, gathering the experiences of people immersed in the rehabilitation journey, would be essential.

2.2 Ontology, epistemology, methodology and methods

The philosophical perspective underpinning this research is critical realism, based on the work of Roy Bhaskar in the 1970s. To understand critical realism, it is necessary to explain ontology and epistemology as viewed within critical realism.

Ontology is about the nature of the world and of reality (Fletcher, 2017; Willig, 2013b). It asks what is there to know, what is real (Scotland, 2012). Ontological positions make assumptions about the kinds of things that can or do exist and define boundaries as to the ways they exist (Lewis-Beck et al., 2004). Essentially, there are two ontological frameworks regarding the nature of the world; realism and relativism (Willig, 2013b). Realism holds that an independent reality exists, separate from perceptions, theories and constructions (Maxwell & Mittapalli, 2010). The world is viewed objectively, as an entity that is ordered and operates according to defined laws and principles (Vincent & O'Mahoney, 2018; Willig, 2013b). Relativism, on the other hand, views the world through a different lens, rejecting the assertion of universal truths or principles. Relativists claim that there are multiple realities, that there are diverse interpretations on the nature of the world (Fristedt, 2018; Willig, 2013b).

Epistemology is concerned with the 'how', rather than the 'what' of knowing; how knowledge can be created (Duncan & Nicol, 2004; Scotland, 2012; Willig, 2013a). Epistemologies are often linked to ontological stances, for example realism is often linked with a positivist epistemology. From a positivist perspective, knowledge can be verified, and described quantitatively and factually (Creswell & Plano Clark, 2017; Scotland, 2012; Zovko, 2018). Human behaviour and actions are so complex, however, that attaining certainty with respect to knowledge, is near impossible (Creswell & Creswell, 2018; Zovko, 2018). Postpositivism arose as a response to the excesses of positivism and has largely succeeded the positivist stance. Postpositivists hold that our claims of knowledge are only ever an approximation at best (Creswell & Creswell, 2018; Willig, 2013b; Zovko, 2018). Nonetheless, there is a strong focus on seeking objective knowledge through scientific endeavour, while acknowledging that absolute truth is unattainable.

Knowledge can also be understood through a subjective lens. Alternative stances to positivism, such as constructivism, hold that an objective knowledge, independent of the researcher does not exist, that it is impossible to attain a 'God's eye' point of view (Maxwell & Mittapalli, 2010). Constructivists believe that understandings of the world are socially constructed from the subjective perspectives and standpoints of individuals and groups (Creswell & Plano Clark, 2017; Maxwell & Mittapalli, 2010). The close relationship between researcher, context and phenomenon is emphasised, leading to elucidation of theory and knowledge (Creswell & Plano Clark, 2017; Pluye & Hong, 2014). Constructivism is generally associated with qualitative methodologies such as grounded theory, phenomenology, and ethnography.

Methodology refers to a general approach to research, the way that a researcher may think about how they will acquire knowledge (Mills, 2014). Methods on the other hand, are the nuts and bolts of research. They are the specific techniques and tools used to implement a study (Willig, 2013b). The methods used in this research are shown in Figure 1.

2.3 Critical realism

Critical realism, a philosophy that arose in the 1970s and 1980s based on the work of Roy Bhaskar, is the overarching ontology of the thesis. The philosophy arose as an alternative to the stance of positivism that dictated that knowledge is only verifiable through empirical enquiry (Fletcher, 2017). Critical realism challenges the traditional view that a realist ontology must be tied to the epistemology of positivism. Critical realism takes a divergent approach by marrying a realist ontology with a constructivist epistemology. Bhaskar's rationale for this was that although an independent, objective reality exists (realist ontology), realities can only be discovered via the language and perspectives of people immersed in those realities (constructivist epistemology) (Fletcher, 2017; Yucel, 2018).

This research is invested in discovering deep meanings and contexts, a basic premise of critical realism. Critical realists hold a belief about multiple layers of reality: the empirical, actual and the real, and that the world is much more than what can be observed or measured (Fletcher, 2017; Williams et al., 2017). At the deep level of 'the real', the imperative for researchers is to investigate the mechanisms and contexts by which phenomena occur (Vincent & O'Mahoney, 2018). Critical realist research is contextualist in its approach to knowledge, context is not a variable to be controlled for but rather an essential component of the research process (Nairn, 2012). There is a mandate to not only understand if something works, but who it works for and under what conditions (Ackroyd & Karlsson, 2014, p. 39). Generation of such data requires methods of social inquiry where individuals are engaged with, in deep, relational ways (Nairn, 2012; Williams et al., 2017).

Critical realism frequently underpins health research where there is a need to investigate complex social phenomena and answer questions that are not easily answered via positivist methods of scientific enquiry (Barolia et al., 2013; Williams et al., 2017). People are different, and injuries affect individuals in profoundly different ways. Equally, responses to health interventions differ between people. Although one person may respond to an intervention in a certain way, another person may respond in an entirely different manner altogether. It is these variations that make rehabilitative practice challenging as there is no formula that can be applied equally to all persons. Critical realism promotes research that investigates the mechanisms and contextual influences of health interventions and was therefore seen to be a philosophy coherent with research that aimed to investigate the complexities of occupation as a rehabilitative tool.

Another way that the ontology of critical realism informs the research in this research is with respect to Bhaskar's beliefs about open and closed systems. Bhaskar was critical of the way that much knowledge is determined in tightly controlled closed systems such as laboratories or within the rigid boundaries of the scientific method (McEvoy & Richards, 2006). Critical realists argue that the social world is an open system where the world is multi-dimensional and unpredictable. Researchers therefore seek to understand the effects of interventions as they occur in the real-world (Fletcher, 2017; Williams et al., 2017). Critical realism guided the development of the studies in this research by mandating open systems research. The research in this thesis is therefore conducted in the participant's home rather than a clinic or laboratory setting. Qualitative research that allows realities to be discovered via the language of participants is also an example of open-system research.

2.4 Mixed methodology research

This research approach used in this thesis is mixed methodology, a research paradigm that uses both qualitative and quantitative methods in the quest for knowledge (Timans et al., 2019). Mixed methodology functions as a guide for selecting specific methods best suited to individual research questions (Timans et al., 2019). The term differs from mixed methods which refers to a single study that employs both quantitative and qualitative methods (Tariq & Woodman, 2013). Qualitative research may be described as the analysis of experiential and social data, while quantitative research focuses on numerical analyses and comparisons (Halcomb 2014). In reality, research is not so dichotomous. Frequently, researchers cross the qualitative/quantitative divide, for example by reporting statistics in a narrative manner or using numbers to report socially acquired data (McEvoy & Richards, 2006). Mixed methodologies are particularly useful for situations where minimal previous research has been undertaken. The advantages of using a mixed methodology approach is that it can build on the strengths of both qualitative and quantitative approaches, while offsetting the biases associated with a single-method approach (McEvoy & Richards, 2006). The data generated are likely to be deeper and more complete, leading to robust and clinically useful information (McEvoy & Richards, 2006). Taken together, the findings from qualitative and quantitative studies provide differing but complementary viewpoints of the same phenomena. Findings may both corroborate and contradict each other but will add deeper knowledge about the phenomena under question.

Mixed methodology has been described as appropriate for research underpinned by critical realism because of the way it avoids conflating a realist world view (ontology) with positivist research methods (epistemology) (Creswell & Plano Clark, 2017, p. 40). Critical realism acknowledges that at best, knowledge is partial, incomplete and accepts that scientific knowledge is best gained through multiple perspectives (Maxwell & Mittapalli, 2010). Increasingly, critical realism is used to underpin mixed methods research (Creswell & Plano Clark, 2017, p. 40; Williams et al., 2017).

In this doctoral work, two systematic reviews and two primary studies comprise the research. The reviews quantitively evaluated and compared data from across multiple studies and provided a narrative synthesis of the results. The first primary study used predominantly qualitative methods and the second quantitative methods. In the qualitative study, the methodology of Interpretive

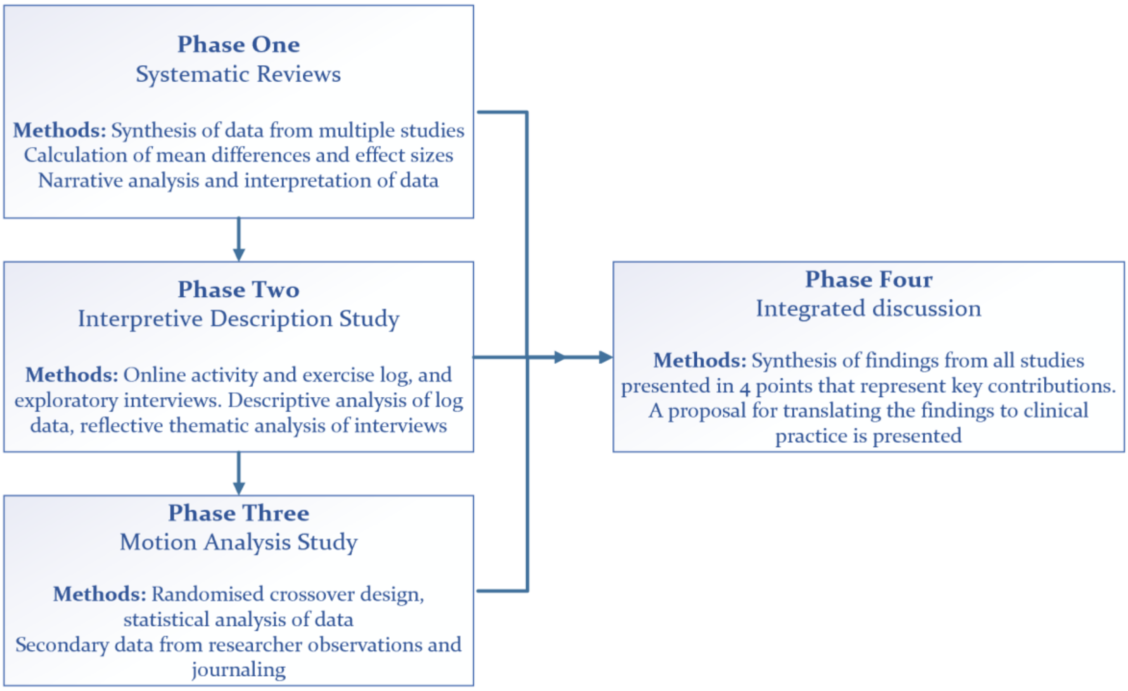
Description was used. Data were generated through exploratory interviews with people in the early weeks of rehabilitating from a wrist injury. The study explored existing concepts and illuminated previously unknown viewpoints about the role of occupation during early rehabilitation. The study also generated a small amount of numerical data via the online activity and exercise log. The qualitative study was a prequel to the second primary study (study IV) and helped to inform the design of that study by identifying purposeful activities that could be suggested to participants. Another objective of the study was to acquire information that could be used to inform future intervention development, a well-recognised function of qualitative research (Creswell & Plano Clark, 2017; McEvoy & Richards, 2006).

The second primary study used predominantly quantitative methods to objectively investigate the premise that occupation can be used to elicit wrist movement in a surgically repaired distal radius fracture. Quantitative research is founded in the postpositivist worldview where knowledge is garnered through the scientific method. The strength of quantitative research is that it can test complex concepts and relationships. Hypotheses can be established and studies designed to compare the actions and effects of interventions under more tightly controlled conditions (McEvoy & Richards, 2006). The study used objective measurement and statistical testing to compare movement outcomes. Like the qualitative study there was some crossing of the qualitative/quantitative divide. During the research, I kept a researcher journal that recorded observations and insights from participants that added depth to the interpretation of the statistical analyses. These researcher observations are reported in Chapter 10 and contribute to a deeper understanding of the meanings and contexts of the role of occupation in early wrist injury rehabilitation.

The sequencing of the studies and the way the research in this thesis was constructed based on mixed methodology is illustrated in Figure 1.

Figure 1

Thesis research frameworks and study sequence



2.5 Summary

Chapter 1 and Chapter 2 defined the aims, structure, sequence and, underpinning philosophical perspectives of the thesis. The following chapter introduces the nature of the clinical problem and the concepts of occupation as a rehabilitative strategy.

Chapter 3 Setting the scene

3.1 Chapter overview

In this chapter I present the concepts and theoretical perspectives that underpin the thesis and provide a rationale for the studies. First, I describe distal radius fractures, how they are treated, and the problems that can arise during postoperative recovery. Next, an overview of occupation is presented. I define the terms activity, occupation and occupation-based interventions and discuss these concepts in the context of distal radius fracture rehabilitation.

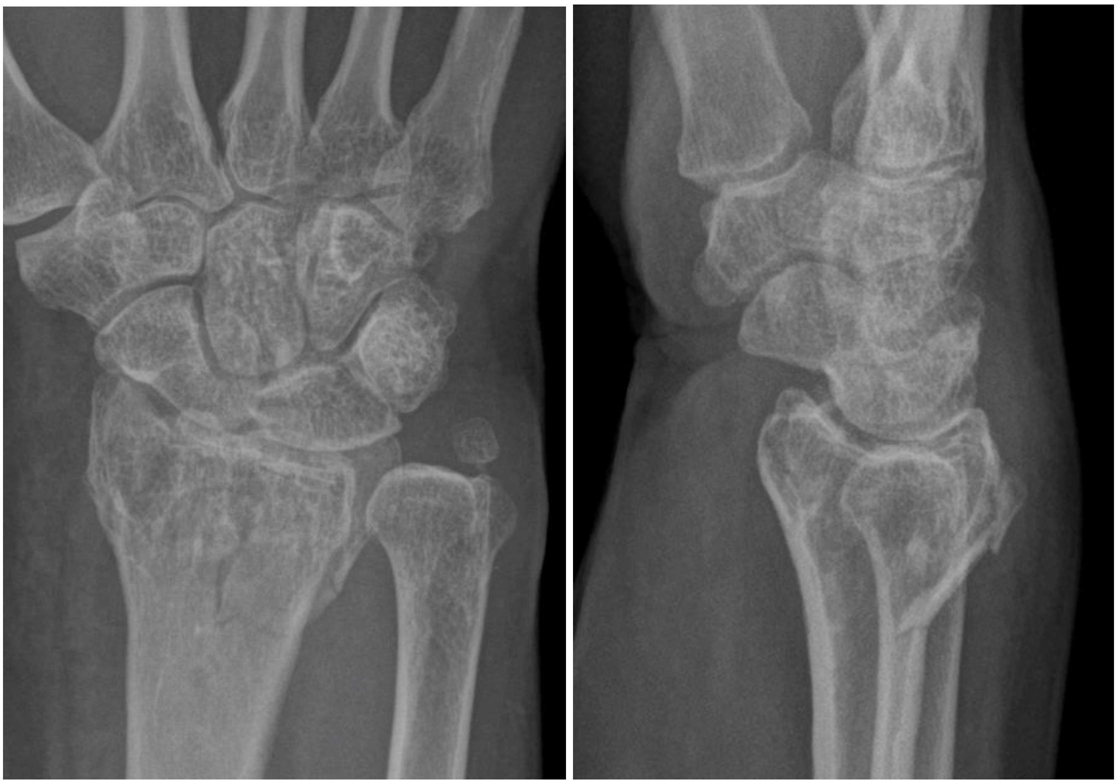
3.2 Distal radius fractures

3.2.1 What is a distal radius fracture?

A fracture to the distal end of the radius is a common upper extremity injury, typically resulting from a fall onto an outstretched hand. Fractures occur in this region of the radius because the cortical bone is thinner making it more vulnerable to giving way under load (MacIntyre & Dewan, 2016). Distal radius fractures can be a simple extra-articular type or more complex where there is significant comminution and involvement of the radio-carpal joint surface. There are various systems used to classify fractures of the distal radius. The AO (Arbeitsgemeinschaft für Osteosynthesefragen) system is widely used and classifies fractures according to articular involvement. Type A are extra-articular, Type B denotes partial disruption of the articular surface, and Type C are fractures with complete articular involvement. Type C fractures, as illustrated in Figure 2, are complex, unstable fractures where the bone has fragmented into multiple pieces, and extend into the radiocarpal joint (Schneppendahl et al., 2012).

Figure 2

Radiographs showing a severely comminuted right intra-articular distal radius fracture



Note. Case courtesy of Dr Joachim Feger, Radiopaedia.org, rID: 81337. From Radiopaedia. (Distal radius fracture | Radiology Case | Radiopaedia.org). Reprinted with permission.

3.2.2 Management of distal radius fractures

Distal radius fractures can be managed conservatively by four to six weeks of cast immobilisation or operatively via open reduction internal fixation (ORIF). Although there is debate as to the relative indications for surgical intervention, the majority of minimally or non-displaced, extra-articular (Type A) distal radial fractures are managed conservatively (Handoll & Elliott, 2015; Schneppendahl et al., 2012). On the other hand, comminuted, intra-articular fractures (Types B3 and C), which make up around 20-50% of all distal radius fractures (Bentohami et al., 2014; Brogren et al., 2007; Koo et al., 2013), are generally managed with surgical fixation, in order to achieve anatomical reduction and stabilisation of the fracture (Keizer et al., 2013). ORIF is now predominantly carried out via a volarly placed locking plate, as shown in Figure 3. These plates were developed in the early 2000s to replace the traditional dorsally placed plates (Cherubino et al., 2010;

Javed et al., 2015). Volar locking plates are anatomically contoured to fit the volar surface of the distal radius where the cortex is thicker and stronger; they maintain reduction of dorsally displaced fractures well, and due to their placement deep to pronator quadratus, protect the flexor tendons from attrition rupture (Loisel et al., 2018; Orbay & Touhami, 2006; Quadlbauer et al., 2017). Volar locking plates are said to have fewer complications than dorsal plates or k-wire fixation and their use is now widespread (Ikpeze et al., 2016; Loisel et al., 2018).

Figure 3

Frontal and lateral radiographs of a distal radius fracture with a volar locking place in situ

Note. Case courtesy of Dr Balint Botz, Radiopaedia.org, rID: 81408. From Radiopaedia. (Distal radius fracture - volar locking plate fixation | Radiology Case | Radiopaedia.org). Reprinted with permission. CC BY-NC-SA 3.0

3.2.3 Epidemiology

Distal radius fractures have a bimodal distribution of incidence, with high occurrence in children under the age of 18, and adults over age 65 (MacIntyre & Dewan, 2016), and a much lower incidence in the 18-65 year age group (Karl et al., 2015). Studies report that between 1.5% and 16% of all emergency department visits are due to distal radius fractures (MacIntyre & Dewan, 2016; Nellans et al., 2012) and are the most common upper extremity fracture (Karl et al., 2015). In a study from the United Kingdom the overall incidence of distal radius fractures in 2016 was 107/100,000 person-years, based on the population of people in Leicester and the surrounding counties (Stirling et al., 2018). Rates of fractures are higher in women. In that study there was a male: female ratio of 32%:68% over the study period of 2008 to 2016 (Stirling et al., 2018). The incidence of distal radius fractures is known to rapidly increase in women after the age of 45 years (Wilcke et al., 2013). In women over 65 years the risk of sustaining a distal radius fracture is around five times higher than for men, largely due to lower bone mineral density following menopause (Dewan et al., 2017). Worldwide, the incidence of distal radial fractures appears to be increasing, which is likely due to the rising numbers of independent, active older adults (MacIntyre & Dewan, 2016; Nellans et al., 2012).

In Aotearoa, New Zealand, distal radius fractures are also common. National data are not published but incidence is illustrated by local data obtained from Counties Manukau District Health Board (CMDHB), a large, predominantly urban geographical region in the north of the country. During 2017 and 2018, in CMDHB, a total of 1397 patients were admitted for fractures of the lower end of the radius, with 41% of these undergoing surgeries (data obtained from CMDHB Health Intelligence and Informatics). The highest rates of surgery for fractures to the distal radius was in the 50-to-59-year aged group where 114/201(57%) of patients underwent surgery. In Aotearoa, New Zealand, the indigenous people are Māori. Of these 114 patients, 10(9%) were Māori compared with 70(61%) who were NZ European. Māori make up around 16.7% of the population and frequently have poorer health outcomes than Non-Māori (Robson et al., 2015). It is considered essential that Māori data are reported to highlight inequities in service provision and health outcomes (Ministry of Health, 2014). Given this, data relevant to Māori are reported in my studies.

3.2.4 Rehabilitation following surgery

After surgical fixation of a distal radius fracture, it is common practice for patients to be referred for rehabilitation under the guidance of a hand therapist. A hand therapist is an occupational- or physio-therapist specialised in the rehabilitation of hand and upper extremity disorders. Rehabilitation following surgical treatment of a distal radius fracture commonly includes early mobilisation. Early mobilisation refers to the practice of initiating motion of the wrist within two weeks of surgery (Inclan & Dy, 2021). One of the key advantages of surgical treatment is that the rigid fixation afforded by volar plates allows for early mobilisation of the operated wrist. Initiating movement early after surgery is important because it helps in the prevention of stiffness and activity limitations frequently associated with this injury (Loisel et al., 2018; Osada et al., 2008; Salibian et al., 2019).

Despite the widely discussed practice of early mobilisation, there is no consensus on the optimal timeframe for commencing mobilisation after surgical treatment of a distal radius fracture (Handoll & Elliott, 2015; Klein et al., 2015; Quadlbauer et al., 2017). Mobilisation and light activity are often initiated from as early as a few days postoperatively (Gong et al., 2015; Osada et al., 2008), but immobilisation for up to six weeks after surgery also remains common practice (Lichtman et al., 2011; Salibian et al., 2019). In the centre where I practice as a hand therapist, it is usual for patients to be referred for hand therapy at their first postoperative appointment at 7-10 days after surgery. At that hand therapy appointment active ROM exercises are taught and a protective, removable splint or wrist brace such as those shown in Figure 4 and Figure 5, is provided. Referral patterns vary widely and not all patients who undergo surgical treatment of a distal radius fracture receive early mobilisation. Even within the geographical region of Auckland, there are differences between services that perform orthopaedic surgery. Some surgical services routinely refer patients for early mobilisation while others apply a cast and delay mobilisation until four to six weeks postoperatively.

Figure 4

Example of a removable custom-made thermoplastic splint used postoperatively

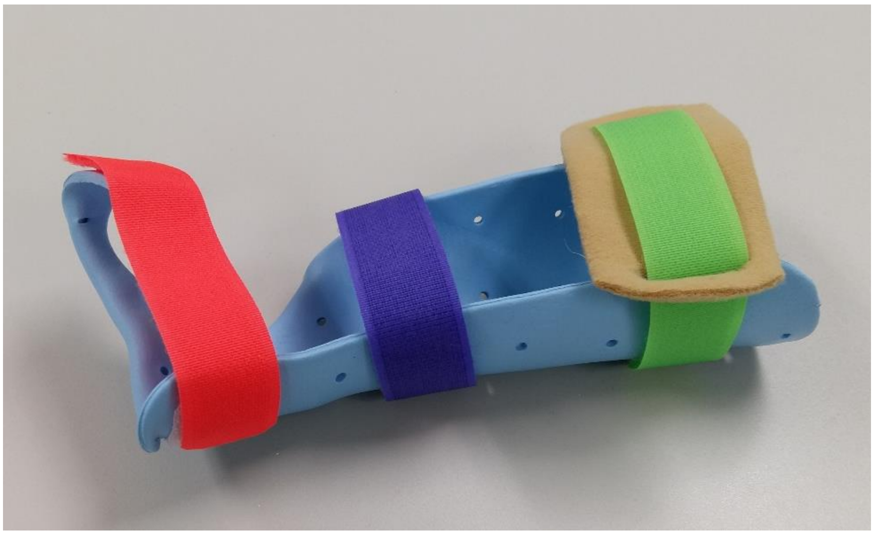


Figure 5

Example of a removable commercial wrist brace used postoperatively

Note. Image is "Wrist Brace" courtesy of Birdies100. From Creative commons. (https://search.creativecommons.org/photos/3414375f-7eb2-4558-b845-de0b15b782e7). Reprinted with permission. CC BY-SA 2.0.

Hand therapists traditionally achieve mobilisation of the operated wrist by prescribing ROM exercise repetitions performed at specified intervals throughout the day (Quadlbauer et al., 2020; Smith et al., 2004). Range of motion exercises have defined parameters, can be applied equally to all patients, and are controllable with respect to dosage, joint range, and duration. It is relatively straightforward to progress home exercise programmes and they can be taught via demonstration, written information sheets, and electronic applications. Many postoperative home exercise programmes are described in the literature for distal radius fractures (Krischak et al., 2009; Quadlbauer et al., 2020; Watson, Haines, et al., 2018).

Despite the frequent use of exercise regimes, the efficacy of such programmes and the need for formal postoperative rehabilitation has been questioned (Kooner & Grewal, 2021; Quadlbauer et al., 2020). A 2017 systematic review found that prescribed exercise programmes may be no more effective than advice or no intervention following an upper limb fracture in improving activity and reducing disability (Bruder et al., 2017). Another criticism of exercise approaches is that they may fail to promote functional motion and do not replicate the demands of muscles during everyday activities (de Vreede et al., 2004; Guzelkucuk et al., 2007; Liu et al., 2014). In addition, adherence to home exercise programmes is variable and may not achieve the dosage of movement required to resolve motor impairments (Bassett, 2003).

There have been repeated challenges to the premise that focusing on physical parameters such as range of motion or grip strength, directly translates to improvements in functional performance (Bialocerkowski et al., 2003; Dekkers & Soballe, 2004; Tremayne et al., 2002). Studies in orthopaedic and neurologic populations have shown that improvements in physical capacity do not necessarily equate to increased function of the affected limb (Bialocerkowski et al., 2003; Dekkers & Soballe, 2004; Karnezis & Fragkiadakis, 2002). Despite this, rehabiliation following surgical treatment of a distal radial fracture remains largely focused on the use of exercise-based interventions, particularly in the early phases where there may be restrictions on loading of healing tissues (Quadlbauer et al., 2020).

Another therapeutic approach to improving wrist range of movement is through performing activities that promote wrist movement in the directions of greatest movement loss. Occupational therapists have long used activity and occupation as therapeutic tools to elicit desired movement (Nelson & Peterson, 1989). The specified use of daily activities, however, does not appear to be a routine component of early mobilisation regimes and the degree to which activity is advocated without a wrist splint is often unclear (Chung, Petruska, et al., 2007; Fowler & Ilyas, 2013; Keizer et al., 2013). For example, some centres encourage light activity such as dressing and lifting up to 2.5 kg, without a splint, from as early as a few days after surgery (Gong et al., 2015; Orbay & Touhami, 2006; Osada et al., 2008). Conversely, functional use and lifting may be delayed until four or six weeks (Chung, Kotsis, et al., 2007; Ydreborg et al., 2015), or only allowed with a brace in situ (Klein et al., 2015; Smith et al., 2004).

It is the therapeutic use of activites and occupation that is the focus of this thesis. It is propsed that daily activities and occupation can be safely used to resolve wrist stiffness and recover functional use of the wrist after surgically repaired distal radius fractures. Specified performance of daily activities will be explored from various perspectives in this doctoral research.

3.2.5 Safety of early mobilisation

To consider the use of daily activity performance in the early weeks after surgery it is first necessary to understand the safe loading limits of surgical volar plates. A large body of biomechanical research has been conducted to evaluate whether surgical volar plates are strong enough to withstand the forces of postoperative rehabilitation (Alluri et al., 2015; Kim et al., 2017). Such studies test the strength of volar plates by applying cyclic and axial loads in cadavers or bone models at forces estimated as equal to early rehabilitation (Putnam et al., 2000). The plates are then usually stressed to the point of failure.

The load transmitted to the wrist during ROM exercises and light daily activity has been calculated in various ways. The load is estimated at around 100 Newtons (N) (Alluri et al., 2015; Dahl et al., 2012; Osada et al., 2003). A grip of 10 N (1kg) is said to exert 26 N of load through the distal radius and the motion of wrist extension 54 N of load (Putnam et al., 2000; Rikli et al., 2007). Some studies suggest greater load transmission of up to 300 N based on transmitted loads to the radius during grip, weight-bearing, and wrist extension (Koh et al., 2006; Mathiowetz et al., 1985; Smith et al., 2018).

Various iterations of volar locking plates have been tested in simulated extra-articular and intra-articular distal radius fractures. In extra-articular fractures studies report that volar plates are sufficiently strong to withstand loads of up to 300 N and in some studies as much as 800 N (Alluri et al., 2015; Cooper et al., 2007; Dahl et al., 2012; Kim et al., 2017; Koh et al., 2006; Levin et al., 2008; Osada et al., 2003). Testing of implants in comminuted intra-articular fractures has also been conducted demonstrating the ability of volar plates to withstand the physiological loads expected during early mobilisation (Kamei et al., 2010; Moss et al., 2011). Even in osteoporotic bones loads greater than 100 N were required for implant failure in complex fractures (Mansuripur et al., 2018).

Taken together, there is strong consensus that surgical volar locking plates are sufficiently strong for the loads transmitted during mobilisation and light daily activities after volar plating of a distal radius fracture (Quadlbauer et al., 2020). It is essential that the loads transmitted to the radius will not cause implant failure, loosening of the screws or loss of fracture reduction while the bone is healing (Alter et al., 2018). Limiting grip force to 17kg in the first 4-6 weeks has been suggested as an acceptable limit (Brehmer & Husband, 2014; Naughton & Algar, 2021) based on the work of Putnam et al. (2000). People can be educated as to what 17 kg represents by gripping a dynamometer in the non-affected hand and avoiding activities that require strong or forceful grip such as using a manual can opener or gripping a hammer.

3.2.6 Sequelae of distal radius fractures

After surgery, the majority of people are able to perform most usual daily activities by three to six months, as measured by self-report scales such as the Disabilities of the Arm, Shoulder and Hand (DASH) and the Patient Rated Wrist Evaluation (PRWE) (Watson, Haines, et al., 2018; Wilcke et al., 2011) . Surgical complications are relatively uncommon but in some patients' motor impairment and disability can persist for many years after surgery (Alter et al., 2018; MacDermid et al., 2007; MacFarlane et al., 2015). Given that distal radius fractures are such a common injury, even small percentages of poor outcomes represents disability in many thousands of people each year (Lalone et al., 2017). The most common problematic sequalae of surgically repaired distal radius fractures are disability, pain, joint stiffness, and sensorimotor impairment.

Disability

Although good functional outcomes are generally reported after volar plate fixation persistent disability occurs in a certain percentage. One study reported that 24% of a cohort of 187 patients had a score of >20/100 on the PRWE, indicating activity limitations (MacFarlane et al., 2015).

Pain

Complex regional pain syndrome (CRPS), a presentation of debilitating persistent pain, occurs in around nine percent of patients after surgical treatment of distal radius fractures (Roh et al., 2014). Additionally, many patients exhibit some of the symptoms of CRPS but may not be formally diagnosed. In a study that included patients with surgically repaired distal radius fractures, it was found that 70% of patients reported at least one symptom of CRPS (Hall et al., 2016). Persistent pain can significantly impact an individual's quality of life and psychological wellbeing (Mehta et al., 2011).

Stiffness

Joint stiffness refers to a limitation of joint motion caused by tightness or shortening of soft tissues surrounding joints (Glasgow et al., 2010). Stiffness of the fingers, wrist, or distal radio-ulnar joints (DRUJ) is another potential sequela of surgically repaired distal radius fractures. Studies suggest that prolonged finger, wrist or DRUJ stiffness occurs in up to 35% of all patients following surgical treatment of distal radius fractures (Egol et al., 2014; Javed et al., 2015; Kong et al., 2020; Lucado et al., 2008). Although wrist stiffness can be adapted to and lived with, it is associated with patient dissatisfaction, poorer functional outcomes, and lower quality of life (Bialocerkowski & Grimmer, 2004; Chung & Haas, 2009; MacDermid et al., 2002). People do not like having a stiff wrist. Patients are satisfied with their recovery when they have regained 79-95% of wrist motion compared with the contralateral wrist (Chung & Haas, 2009; Chung et al., 2020). Similarly, finger stiffness is a strong predictor of functional loss (Egol et al., 2014;

Kirby & Sparrow, 2017; Yang et al., 2018). Patients with wrist and finger stiffness require treatment for longer durations and require a greater number of hand therapy visits to obtain satisfactory outcomes (Kirby & Sparrow, 2017; Yang et al., 2018).

Wrist extension, supination, and ulnar deviation ROM limitation

A consistent finding in the literature is that the movements of wrist extension, ulna deviation and supination are stronger predictors of functional outcomes than wrist flexion, pronation and radial deviation. Lucado et al. (2008) and Yang et al. (2018) showed that poorer wrist extension predicted worse DASH scores at, $p=0.011$ and $p<0.0001$ respectively and similarly for supination, $p=0.02$, and $p<0.001$. Wilcke et al. (2007) reported that <85% wrist extension was correlated with DASH scores of greater than 22, representing worse disability. Supination strength and ROM has been reported as a predictor of functional outcomes (Ploegmakers et al., 2015; Swart et al., 2012). Loss of ulna deviation has been strongly correlated with poorer DASH scores (Wilcke et al., 2007; Yuan et al., 2018). Wilcke et al. (2007) reported that <80% ulna deviation of the contralateral limb was correlated with DASH scores of greater than 18. MacDermid et al. (2002) found a moderate associated between a composite measure of wrist ROM and poorer PRWE scores. Given that wrist extension, supination, and ulnar deviation were found to be most associated with activity limitations, the research conducted in study IV focused on these movement directions.

Sensorimotor impairment

Studies have demonstrated a spectrum of sensorimotor impairments following surgical and non-surgical treatment of distal radius fractures. These include reduced sensibility and proprioception, tremor, poor coordination, hesitancy, and slow execution of movement (Bialocerkowski, 2002; Hall et al., 2016; Imai et al., 2018; Karagiannopoulos et al., 2013; Mehta et al., 2011; Nazari et al., 2018; Seo et al., 2011; Wollstein et al., 2018). Interventions that address sensorimotor deficits after distal radius fracture are now commonly advocated as part of postoperative rehabilitation (Valdes & Marik, 2010; Wollstein et al., 2018).

3.2.7 Summary

After surgical treatment of distal radius fractures, disability, wrist stiffness and sensorimotor impairments commonly occur. Due to the high incidence and cost of rehabilitating these fractures, it is essential that hand therapists provide rehabilitative strategies to address such sequelae. Hand therapists traditionally rely on exercise routines to restore wrist ROM, but the efficacy of exercise approaches has been questioned. Furthermore, exercise repetitions may be limited in their capacity to elicit functional, complex planes of movement or deliver sufficient therapeutic dosage of movement during the day. Specified use of daily activities and occupations are investigated in this thesis as an alternative or complementary approach to range of motion exercises in the rehabilitation of surgically repaired distal radius fractures.

3.3 What is activity and occupation?

3.3.1 Terms defined

The terms activity and occupation often lack clarity in the literature and are frequently, though inaccurately, used interchangeably (Polatajko et al., 2004). *Occupation* is defined in this thesis as the various life activities in which people engage (American Occupational Therapy Association, 2020). *Occupations* are broad categories that include activities of daily living, rest and sleep, education, work, play, leisure, and social participation. A*ctivities* are smaller actions or sets of tasks that occupations are constructed from; they are the components of occupations (American Occupational Therapy Association, 2020; Polatajko et al., 2004), such as preparing vegetables, getting dressed, or watching a movie. The 2004 taxonomic code of occupational performance provides a useful delineation of activities and occupations by placing them on a hierarchy (Polatajko et al., 2004). Within the code, occupations are groupings of activities and form the highest level. The lowest levels are those of voluntary joint movements such as wrist extension, and isolated actions and tasks such as lifting a cup or closing a door. The levels from lowest to highest are voluntary movement, movement pattern, action, task, activity, occupation, occupational grouping. Activities therefore sit between tasks and occupations and hence understood to be more than a task or series of joint movements but less than an occupation (American Occupational Therapy Association, 2020; Polatajko et al., 2004).

Activities and occupations are frequently used by occupational therapists during rehabilitation to address occupational performance and impairments (Colaianni & Provident, 2010; Hétu & Mercier, 2012). Such approaches are known as occupation-based interventions and defined, based on the work of Fisher (2014), as those where occupation is specified as the therapeutic agent of change. It is implied that patients are active in the process of defining what is meaningful to them and perform those occupations as therapy (Hansen et al., 2016). The premise that engaging in a meaningful occupation yields different results from a non-purposeful task, underlies occupational therapy (Nelson & Peterson, 1989).

One difficulty with the term occupation-based intervention is its apparent focus on occupation which may therefore exclude the use of activities. In hand therapy, activities are often used, in preference to occupations, to promote movement or enhance engagement in therapy (Dy & Yancosek, 2017; Hansen et al., 2016). This is because in early injury rehabilitation, the focus is often at the activity level, where activities are performed intermittently, or graded commensurate with the stage of healing and used as a therapeutic tool, known as *purposeful activities* (Hinojosa & Blount, 2014b). Examples of such activities may be donning an item of clothing, stroking a pet, or washing light dishes. The full performance of occupations such as childcare, gardening or playing football are likely to come later once the healing bone can withstand greater loads. As such, it may be said that *purposeful activities*, rather than occupations are used therapeutically in the early stages of rehabilitation.

In this thesis the term *occupation-based intervention* is used as a broad term to define an intervention that uses activities and/or occupations for the purpose of remediating impairment. The term *purposeful activity* in this thesis refers to specific activities that are intentionally performed to achieve a therapeutic goal (Hinojosa & Blount, 2014b) .

3.3.2 Assumptions of occupation: purpose, meaning, context

Occupation, as used in occupational therapy theory, assumes certain inherent characteristics. These include purpose or utility, meaning to the individual, occurrence within the context of everyday life, and deliberate, intentional engagement (Molineux, 2010; Reed et al., 2013). Occupation is doing, it is an active, intentional engagement in things that matter, those things that a person wants or needs to do during their daily life (Crabtree, 2010; Molineux, 2010).

Critical to the therapeutic use of occupation is the understanding that activities and occupations are perceived as meaningful to the individual (Eklund et al., 2009). According to Persson et al. (2001), the meaning of occupation lies in three domains of value: concrete, symbolic, and self-reward. Concrete value is the tangible result of performing an occupation – observing a job well-done or experiencing satisfaction from a task completed. The symbolic value of occupation lies in the deeper personal meaning that an occupation represents. Self-reward relates to the enjoyment and pleasure that comes from performing a chosen occupation. The juncture at which the physicality and emotionality of occupation intercepts with recovery from injury, is under investigation in this thesis.

3.3.3 Why does occupation matter?

This thesis explores the concept that activities and occupation have discrete effects and mechanisms in bringing about improvements after surgical treatment of a distal radius fracture. Increasing evidence exists for the benefits of occupation-based interventions in rehabilitative practice such as falls prevention, neurorehabilitation, and older adults (Clemson et al., 2010; Liu et al., 2014; Orellano et al., 2012). In hand therapy, beneficial motor and functional outcomes have been reported for patients receiving an occupation-based intervention (Colaianni & Provident, 2010; Daud, Yau, Barnett, Judd, et al., 2016; Weinstock-Zlotnick & Mehta, 2018). It is increasingly suggested that participation in meaningful occupations be part of routine rehabilitation following upper limb injury (Harris et al., 2005).

Although there is emerging evidence for the efficacy of occupation-based interventions in people with hand and wrist injuries (Weinstock-Zlotnick & Mehta, 2018), fewer studies have explored the mechanisms by which activities and occupation bring about change. Commonly discussed actions include familiarity of movement, augmented movement volume, distraction from pain, and preservation of sensorimotor function. Performance of activities may act by taking advantage of motor patterns that are familiar and replicate the multiplanar, composite motions required for activities of everdyay life (de Vreede et al., 2004). Multiple and varied activities throughout the day may expose stiff joints to greater dosages of movement than intermittent exercise (Daud, Yau, Barnett, Judd, et al., 2016). It has been suggested that participating in meaningful activities and occupations may have an ameliorating effect on pain, by focussing attention away from uncomfortable movement onto the activity itself (Weinstock-Zlotnick & Mehta, 2018). Performance of activities and occupations may assist in promoting the reorganisation of cortical maps and ameliorating the effects of over-protection of the operated limb, seen in a subset of individuals after distal radius fracture (Lissek et al., 2009; Mehta et al., 2011). This effect may be even more important during early phases of recovery, when maladaptive motor patterns are most likely to be established (Imai et al., 2020)

In my clinical role as a hand therapist, I have often observed the effects of activity performance on motor performance. Movement can be difficult to initiate and performing a simple task sometimes appears to elicit movement with greater ease or with less pain or anxiety than during an exercise repetition.

3.3.4 What don't we know about the influence of occupation?

The theoretical knowledge on how occupation influences movement and remediates activity limitations following upper limb injury is limited. The safety of performing daily activities in the early weeks of recovery has not been established and the patient's perspectives on the influence of activity and occupation on recovery has not been fully explored. There are no known studies where movement has been objectively measured during purposeful activities in the early weeks following hand or wrist injury. Without empirical evidence and a foundational understanding of the ways that activity and occupation influences recovery in this population, it remains challenging for therapists to use purposeful activity as a rehabilitative strategy.

3.4 Summary

Chapter 3 discussed distal radius fractures and the problem of postoperative stiffness. Postoperative rehabilitation was discussed, and occupation-based therapy put forward as a potential therapy to address wrist stiffness and functional recovery after surgery. The chapter concluded with a discussion on theoretical perspectives and concepts of occupation. The following chapter represents the first phase of research into understanding the role of activities and occupation in the recovery from surgically repaired distal radius fractures.

Chapter 4 Published study I: Influence of purposeful activities on upper extremity motor performance: A systematic review

4.1 Chapter overview

This chapter presents the first systematic review undertaken (study I). The objective was to analyse the evidence for how movement occurs in the context of purposeful activity as opposed to arbitrary or non-purposeful movement. Previous reviews provided evidence for enhanced motor performance during purposeful activity in predominantly neurological disorders and in upper and lower limb performance combined (Hétu & Mercier, 2012; Lin et al., 1997; Nelson & Peterson, 1989). There were no known reviews that investigated the evidence from a solely upper limb or musculoskeletal injury perspective.

Chapter 4 addresses RQ1: Does performance of purposeful activities and occupation influence upper extremity motor performance differentially from exercises or non-purposeful movement in healthy and musculoskeletal injury populations?

The manuscript was published in OTJR: Occupation, Participation and Health (Collis et al., 2020b). The full citation for the article is:

Collis, J. M., Signal, N., Mayland, E., & Wright-St Clair, V. A. (2020). Influence of purposeful activities on upper extremity motor performance: A systematic review. *OTJR: Occupation, Participation and Health, 40*, 223-234. https://doi.org/10.1177/1539449220912187

The manuscript is included here with citations, figures and tables formatted consistent with the thesis. A copy of the published article is found in Appendix A.

4.2 Published article

4.2.1 Abstract

Following upper extremity injury, exercise-approaches are commonly used to address motor impairments. Occupation-based approaches are also used but less widely promoted and their mechanisms of action not well-understood. Movement performed during purposeful activities and occupations may yield

better motor performance than during non-purposeful tasks. This review investigated the influence of engagement in purposeful activities and occupations on upper extremity motor performance in healthy and musculoskeletal populations. Databases were searched for studies in healthy or upper extremity musculoskeletal-injured adults, that compared motor performance during purposeful activities against non-purposeful movements. Twenty-one studies of moderate quality, conducted predominantly in healthy populations, were included. Upper extremity movement quantity and quality were enhanced when performed during purposeful conditions. Purposeful activities have potential to be used following injury to enhance movement and address motor impairments to a greater extent than is currently promoted. Research in musculoskeletal populations is required.

4.2.2 Introduction

Trauma or pathology to the wrist or hand can result in impairment and issues with performance of daily occupations that can persist for weeks or months following injury. Sensorimotor impairments include pain, joint stiffness, weakness, poor dexterity, impaired sensory discrimination and disrupted body perception (Karagiannopoulos et al., 2013). Patient satisfaction is low and functional outcomes are poorer among patients with such impairments (Chung & Haas, 2009). Qualitative and observational data confirm the long-term functional impacts, with individuals often obligated to adopt compensatory strategies such as allowing longer time, using the contralateral hand or changing the type of grip, in order to carry out daily activities, (Bialocerkowski, 2002).

Occupational, physical or hand therapists use a range of approaches to restore motion and function to the upper extremity following injury. Therapy often has a strong focus on range of movement exercises, particularly in the early weeks of healing (Bruder et al., 2017). Although exercises are fundamental to wrist and hand injury rehabilitation, they may be no more effective in reducing physical impairments than advice or no intervention (Bruder et al., 2017). Movement can also be intentionally promoted during daily activities and occupations but is less widely described in the literature as a therapeutic approach, than exercise approaches (Colaianni & Provident, 2010; Dy & Yancosek, 2017), Clinical observations suggest that therapists frequently use purposeful activities and occupations to facilitate joint movement, yet the rationale for using activities in this manner remains relatively unexplored. The review addresses the question of whether engaging in purposeful activities and occupations has a beneficial influence on movement of the upper extremity after injury compared with non-purposeful movements or tasks.

Although the terms activity and occupation are sometimes used interchangeably (American Occupational Therapy Association, 2020), it is important to differentiate between them. *Occupation* is defined as the broad categories of daily life activities in which people engage: activities of daily living, rest/sleep, education, work, play, leisure, and social participation (American Occupational Therapy Association, 2020). *Activities,* on the other hand, are the smaller actions or sets of tasks that occupations are constructed from (Polatajko et al., 2004). The term *purposeful activity* is used in this paper to highlight that the activities under investigation are actions and sets of tasks with meaning and purpose, for example using chopsticks or slicing vegetables, as opposed to broader *occupations*.

Approaches that use purposeful activities and occupations therapeutically have demonstrated beneficial effects on impairment and functional outcomes for individuals with upper extremity disorders (Weinstock-Zlotnick & Mehta, 2018). Therapists have been challenged to make meaningful occupations part of routine injury rehabilitation (Dy & Yancosek, 2017; Mehta et al., 2011) yet little is known about the mechanisms by which activities and occupations operate. It has been asserted that occupation-based interventions may be more effective than exercise alone because they: i) promote self-efficacy, motivation and engagement in rehabilitation; ii) promote greater dosage of motion; iii) preserve sensorimotor function; and iv) yield differences in motor performance from those seen during non-purposeful tasks such as exercise (Colaianni & Provident, 2010; Dy & Yancosek, 2017; Hétu & Mercier, 2012; Mehta et al., 2011). For clarity, *motor performance* is defined here as the observable production of a voluntary action or motor skill (Schmidt & Wrisberg, 2008, p. 11), and operationalised as both the quantity and quality of movement including movement duration, repetitions, range, speed and smoothness.

Research in healthy and neurologically impaired populations suggests there is superior motor performance in the upper and lower extremity, when movement is embedded within purposeful activities, compared with movements performed under rote or purposeless conditions (Hétu & Mercier, 2012; Lin et al., 1997). There are no known reviews however, that investigated the influence of purposeful activities on motor performance after upper extremity musculoskeletal injury. Understanding causal mechanisms would elucidate theoretical foundations and be useful in informing the development of interventions that capitalise on the strengths of purposeful activities in promoting movement.

The UK Medical Research Council describes the first phase of complex health intervention development as identifying existing evidence and theoretical models (Craig et al., 2013). A broad-based systematic review that evaluates various study designs and populations contributes to this knowledge base (Squires et al., 2013). Other systematic reviews such as those by Weinstock-Zlotnick and Mehta (2018) and Bruder et al. (2017) have reviewed the efficacy of occupation and exercise interventions. This systematic review differs by focussing on the causal mechanisms of purposeful activities on movement, and the contexts in which they might occur. This systematic review therefore aimed to investigate the influence of purposeful activities on motor performance of the upper extremity in healthy and musculoskeletal injury populations.

4.2.3 Methods

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) recommendations were followed (Moher et al., 2015). The study protocol was registered on PROSPERO (CRD42019135666). In November 2018, the primary author (JC) searched Medline and CINAHL Complete (via EbscoHost) and Emcare and AMED (via Ovid) to identify studies that investigated the effect of purposeful activity on motor performance. A series of preliminary searches were undertaken to identify terms used before 'occupation' gained widespread use. Table 1 details the final search terms and string. Results were exported to EndNote™ X8, citations combined, and duplicates removed. Inclusion criteria are detailed in Table 2. A lower age limit of 16 was set to capture older studies with a younger delineation of adulthood than the currently accepted age of 18. Titles and abstracts were reviewed by (JC) to eliminate studies not meeting the inclusion criteria. Reference lists and citations were screened to identify missed studies. Next, two authors (JC and VW) screened the full-texts of remaining articles to reach a consensus on articles to include.

Table 1

Search Terms and string used in the review

Intervention	Meaningful occupation, activity, or task Purposeful activity Therapeutic occupation Occupationally embedded exercise Materials-based occupation Functional task Added purpose
Outcome	Performance Motor control Motor skill Quality of movement or motion Kinematic Quality or analysis of reach
Search string used for all four database searches	("meaningful occupation*" OR "meaningful activit*" OR "meaningful task*" OR "therapeutic occupation*" OR "occupation* embedd*" OR "materials based occupation*" OR "functional task*" OR "purposeful activit*" OR "add* purpose") AND (performance OR "motor control" OR "motor skill" OR "quality of movement" OR "quality of motion" OR kinematic OR "quality of reach" OR "analysis of reach")

Table 2

Inclusion and exclusion criteria for included studies

Inclusion criteria:
Adults aged ≥16 years
Healthy or with an upper extremity musculoskeletal condition
Published between 1980 and 2018
Evaluation of at least one motor performance variable for the upper extremity
Compared activity or occupation with meaning or purpose against task without meaning or purpose, simulated activity, rote exercise, or movement repetition
Published in English
Original experimental research of any design
Exclusion criteria:
Neurological disorder
Unpublished theses
Systematic or narrative reviews, position papers
Conference proceedings or reports

Data were extracted from the studies by the primary author (JC) using a template including: author and date of publication, study design, population size, participant characteristics, interventions or conditions and results. In studies with healthy and neurological participants, data were reported for the healthy cohort only. For the purposes of clarity, nomenclature for groups and conditions were standardised across studies. The term *purposeful activity* was used to refer to an activity or occupation with purpose; *simulated activity,* where the activity was performed in a non-purposeful manner, and *exercise* for movements performed for the purpose of exercise alone. Motor performance outcomes were reported as mean differences between conditions or groups. Effect sizes were calculated for individual outcomes, on the difference between condition or group, according to Hedges *g,* where 0.2, 0.5 and 0.8 indicates a small, medium and large effect respectively (Cooper et al., 2019). Meta-analysis was not conducted due to the disparate nature of design and purpose, and moderate quality of the studies.

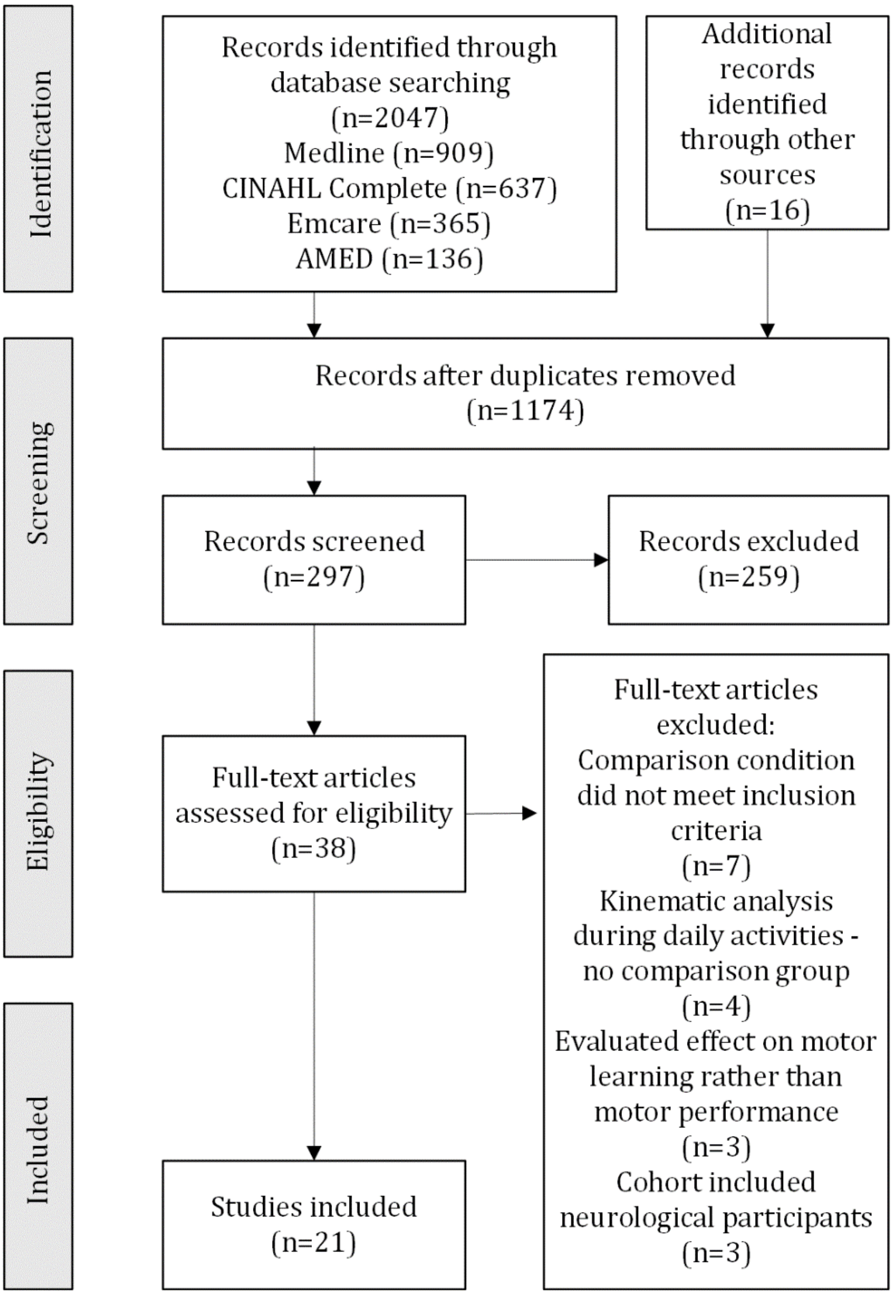
Risk of bias in the included studies was assessed by the primary author (JC) using a modified version of the Downs and Black Quality Index (Downs & Black, 1998). The index is suitable for evaluating group and crossover studies and has good intra- and inter-rater reliability (*r=0.88* and 0.75, respectively) (Downs & Black, 1998). The index evaluates methodological quality of reporting, external quality, internal validity, and power. Questions not relevant to the included study designs were excluded, similar to other systematic reviews that included cross-over trials (Burdon et al., 2017). Scoring was modified from 0-28 to 0-20 where 20 represents studies of the highest quality. A random selection of studies (n=6) was independently scored by another author (EM) to check agreement between assessors. Where scoring differed, consensus was reached through discussion.

4.2.4 Results

The study selection process is detailed in Figure 6. Twenty-one studies were selected for inclusion in the review. There were 831 participants in total, with an age range of 16–81 years. Sample sizes ranged from five to 146 participants. Only one study included a musculoskeletal injury population. In that study, King (1993), recruited 146 patients from a hand therapy clinic, but did not provide details of injury characteristics. Seventeen studies used a randomised cross-over design, and the remaining were group design. In all studies, random assignment was used for sequence or group allocation.

Figure 6

PRISMA flow diagram



Note. PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analysis

The quality assessment scores are shown in Table 3. Six studies were graded by two authors (JC and EM). Agreement was 97.5% so further co-marking was not performed. The mean score was 13.6/20, with a range of 8–18. Recruitment showed evidence of bias in 16 studies. Blinding to the interventions was not possible in any study, but all participants were blinded to hypotheses. In the majority of studies (19/21), it is unclear whether assessors were blinded to the results until completion of data analysis. Randomisation occurred in all studies; only three studies reported a power analysis for sample size. Analysis of variance was conducted in all 17 crossover trials to test for hypotheses and order effects. Risk of carryover effect was deemed to be low in these studies as counterbalancing was used to control for carryover and sequencing effects. With the exception of two studies (Ross & Nelson, 2000; Wu et al., 1998), the condition order had no effect on outcomes. Difference in group or condition means and standard deviations were reported for dependent variables in all studies. No study defined a primary outcome or reported confidence intervals.

Table 3

Scoring of the Downs and Black Quality Index

	Reporting								External validity		Internal validity (bias)					Internal validity (confounding)			Power	Score
Question	1	2	3	4	5	6	7	10	11	12	14	15	16	18	20	21	23	25	27	
Bakshi et al. (1991)	1	1	1	0	1	1	0	1	0	0	0	0	1	1	1	1	1	0	0	11
Fasoli et al. (2002)	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	15
Hall and Nelson (1998)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	14
Holubar and Rice (2006)	1	1	1	1	2	1	1	1	1	1	0	0	1	1	1	1	1	1	1	18
Hoppe et al. (2008)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	0	13
Kehoe and Rice (2016)	1	1	1	1	2	1	1	1	1	0	0	0	1	1	1	1	1	1	1	17
King (1993)	1	1	0	1	0	1	1	1	0	0	0	0	1	0	0	1	0	0	0	8
Lin et al. (1998)	1	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	13
Ma et al. (1999)	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	15
Miller and Nelson (1987)	1	1	0	1	0	1	1	1	0	0	0	0	0	1	0	1	1	1	0	10
Morton et al. (1992)	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	1	1	0	0	10
Rice et al. (1999)	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0	13
Rice et al. (2009)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	14
Rice and Renock (2006)	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	16

	Reporting								External validity		Internal validity (bias)					Internal validity (confounding)			Power	Score
Question	1	2	3	4	5	6	7	10	11	12	14	15	16	18	20	21	23	25	27	
Ross and Nelson (2000)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	14
Sackaloo et al. (2015)	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	0	15
Steinbeck (1986)	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	0	0	14
Taylor et al. (2018)	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	15
Wagner et al. (1995)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	0	0	12
Wu et al. (1998)	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	15
Wu et al. (1994)	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	13

Purposeful activities and motor performance outcomes

Characteristics of the studies and main results are presented in Table 4. The purposeful activities used in the studies included: personal care (Taylor et al., 2018); writing (Ross & Nelson, 2000; Wu et al., 1994); eating (Hall & Nelson, 1998); using chopsticks (Ma et al., 1999; Rice et al., 2009); reaching for candy (Sackaloo et al., 2015), a mug (Holubar & Rice, 2006; Rice et al., 2009), a bell (Lin et al., 1998; Morton et al., 1992) or a magazine (Rice & Renock, 2006); meal preparation tasks (e.g. slicing vegetables or making cookies) (Fasoli et al., 2002; Hoppe et al., 2008; Miller & Nelson, 1987; Rice et al., 1999; Wu et al., 1998); woodwork or handcrafts (Bakshi et al., 1991); and board or computer games, throwing darts or ping-pong (Kehoe & Rice, 2016; King, 1993; Steinbeck, 1986; Wagner et al., 1995).

The range of motor performance outcomes measured varied. Outcomes for quantity of movement were limited to numbers of repetitions, duration of performance and range of movement. Quality of motion was evaluated by velocity, time taken to complete a movement, reaction time, movement units and displacement. Quantity metrics were reported in eight, and quality in 13, studies. Motor performance was measured by 3D motion capture systems, electrogoniometry, computer software or by manual counting or stopwatch. The majority of studies (17/21) found better motor performance in favour of purposeful activity in at least one outcome. In one low-quality study (Wagner et al., 1995), the data were in favour of exercise, and in two low-quality studies (Bakshi et al., 1991; Morton et al., 1992) no differences were observed between groups for any outcome. Many studies found differences for some performance variables and no differences for others.

Quantity of motion: repetitions, duration, and arcs of motion

Seven studies measured the number of repetitions completed during a given time frame or until fatigue. In four of these studies (Hoppe et al., 2008; King, 1993; Miller & Nelson, 1987; Steinbeck, 1986), small to medium effects were found for purposeful activity. Participants performed a greater number of repetitions in occupation groups, with differences reaching statistical significance except in the study by Miller and Nelson (1987). Only three studies measured duration of performance, with participants allowed to work for as long as desired (Hoppe et al., 2008; Miller & Nelson, 1987) or until perceived exertion reached 'very hard' (Morton et al., 1992). The study by Hoppe et al. (2008) showed that participants who stirred cookie dough, performed for longer periods of time than when stirring a concealed bowl of an unknown substance. Similarly, Miller and Nelson (1987) found longer duration of performance in their occupation condition. Differences were non-significant in that study, but with a large effect size. Conversely, no difference in performance duration was found by Morton et al. (1992). The study by Taylor et al. (2018) was the only study that evaluated joint range of motion. Greater arcs of shoulder and wrist motion were required to perform functional activities than simulated tasks, for most of the activities evaluated.

Quality of motion: speed, movement and reaction time, movement units, displacement

Thirteen studies measured various aspects of velocity, with peak velocity being measured most frequently (11 studies). Peak velocity was significantly higher in three studies, lower in four, and equal in the remaining studies. Ten studies measured percentage of movement time to reach or maintain peak velocity, but only five studies found statistically significant differences. Movement time was measured in 13 studies, with eight studies reporting quicker movement during the occupation condition (Fasoli et al., 2002; Holubar & Rice, 2006; Lin et al., 1998; Rice et al., 2009; Ross & Nelson, 2000; Sackaloo et al., 2015; Wu et al., 1994) or virtual reality (Kehoe & Rice, 2016). Large effects were demonstrated in two of these studies (Fasoli et al., 2002; Kehoe & Rice, 2016). A large and significant effect for movement time was also reported by Hall and Nelson (1998) but in the opposite direction, of longer movement time. No difference was observed by Kehoe and Rice (2016) or Rice et al. (1999). Reaction time was measured by Ross and Nelson (2000) and Wu et al. (1998), and was faster during purposeful activity in both studies. Eleven studies measured movement units, an indicator of movement smoothness calculated by summing the number of times acceleration went from negative to positive to negative (Holubar & Rice, 2006; Kehoe & Rice, 2016). Seven of these studies showed small to medium effects of purposeful activity in producing fewer movement units (Rice et al., 1999; Ross & Nelson, 2000; Wu et al., 1994), when participants used their own objects (Holubar & Rice, 2006), reached for preferred items during the experiment (Rice & Renock, 2006; Sackaloo et al., 2015), or were visually exposed to the objects for longer periods of time (Rice et al., 2009). Fasoli et al. (2002) demonstrated a large effect size for one of the four activities (hammering). Displacement was measured in 12 studies, with lower displacement an indication of more direct, controlled movement. In five of these studies, displacement was significantly lower in occupation groups. For example, in the high-quality study by Kehoe and Rice (2016), throwing an actual dart showed less displacement than in a virtual reality dart game.

Table 4

Study characteristics and outcomes

Study	Design and participants	Interventions	Outcomes	Results
Bakshi, Bhambhani, and Madill (1991)	Randomised, counterbalanced, repeat measures two-factor experiment Healthy adult students (n=20) M:F = 0:20 Mean age: 23 years	PA: eight handcraft or woodwork activities SA: same activities performed as a movement repetition Participants selected most and least preferred occupations and performed them under both conditions (PA and SA) in random order for 10 minutes	Number of repetitions during 10-minute session counted manually Participants rated perceived exertion on an ordinal scale (from very, very light to very, very hard) Heart rate measured with a wireless heart monitor and blood pressure measured manually	No significant difference, between PA and SA groups in number of repetitions performed No. of repetitions (PA vs. SA): Most preferred 63.3±33.7 vs. 82.9±39.1, g=-0.54 Least preferred 63.1±31.9 vs. 84.4± 43.6, g=-0.55

Study	Design and participants	Interventions	Outcomes	Results
Fasoli, Trombly, Tickle-Degnen, and Verfaellie (2002)	Randomised, counterbalanced, repeat measures Healthy participants (n=5) M:F = 1:4 Mean age: 58 years	PA: slicing bread, slicing tomato, stirring cup of coffee, hammering a nail. SA (three conditions): same tasks performed with limited or no materials/tools	MT (sec) PV (mm/sec) MUs D (mms) Measured by a motion capture system	Significantly lower PV and less D for all tasks in favour of PA MT faster for slicing bread, slicing tomato and hammering, and fewer MUs for hammering All other data were non-significant Data for hammering PA vs. SA: MT 1.45±0.41 vs. 1.99±0.44, g= 1.15 PV 67.63±25.57 vs. 1271.49±542.76, g=2.83 MUs 6.10± 0.22 vs. 7.00±0.50, g=2.10 D 193.17±96.56 vs. 1153.00± 620.08, g=1.95
Hall and Nelson (1998)	Randomised, counterbalanced, repeated measures College students (n=47) M:F = 0:47 Mean age: 22 years	PA: eating applesauce with a spoon SA (two conditions): same task performed with limited or no materials/tools	MT (secs) PV (cm/sec) MUs D (cm) Measured by a four-camera motion capture system	Significantly longer MT and lower PV in favour of PA Significantly greater MUs against PA. No difference for D PA vs. SA: MT 2.75±0.35 vs. 2.00±0.36, g=2.10 PV 59.3±12.6 vs. 80.2±14.7, g=1.51 MUs (from start to mouth) 13.7±3.6 vs. 4.5±3.0, g= -2.75 D 46.3±7.2 vs. 49.0±11.1, g=-0.29

Study	Design and participants	Interventions	Outcomes	Results
Holubar and Rice (2006)	Randomised, counterbalanced, repeated measures Healthy adults (n=32) M:F = 0:32 Mean age: 44 years	Reaching and placing own mug or mug owned by researcher in a lab or at home	MT (sec) PV (degree/sec) % of MT at PV MUs D (degrees) Measured by an electrogoniometer across the elbow	MT significantly faster when reaching for own mug vs. researcher's mug regardless of location: 0.96±0.21 vs. 1.00±0.22, g=0.18, at home; 0.94±0.23 vs. 0.98±0.20 at lab, g=0.18 Fewer MUs for participants reaching for their own mug in the lab compared with at home: 3.06±1.72 vs. 3.63± 2.46, g=0.27 No other differences observed for mug ownership or location in remaining outcomes
Hoppe, Miller, and Rice (2008)	Randomised, counterbalanced, repeated measures College students, (n=30) M:F = 0:30 Mean age: 22 years	PA: stirring cookie dough. Environment enriched to replicate purposeful activity of making cookies SA: stirring an unknown substance in a covered bowl	Number of repetitions Duration of performance Repetitions counted by researcher; duration recorded by a stopwatch	PA group performed a significantly greater number of repetitions, 80±59 vs. 62±40, $p<0.004$, g= 0.35, for a significantly longer time, 125±80 vs. 109±87 secs, $p<0.012$, g= 0.19

Study	Design and participants	Interventions	Outcomes	Results
Kehoe and Rice (2016)	Randomised, counterbalanced, repeated measures Healthy adults (novice dart players) (n=34) M:F = 15:19 Mean age: 26 years	PA: throwing darts at dart-board VR: throwing virtual darts at a virtual dartboard SA: throwing imaginary darts at a blacked-out dartboard	D (cm) PV (m/sec) MT (sec) % of MT to PV MUs MA (largest distance between thumb and index finger during the throw) Measured by an eight-camera motion capture system, X-box 360, and Kinect sensor	Significant differences for D, PV MT, % of MT to PV and MA in favour of PA or VR: D (PA vs SA) 242.38±85.28 vs. 258.22±128.08, g=0.14 D (VR vs. SA) 168.91±84.91 vs. 258.22±128.08, g=0.81 PV (PA vs. SA) 3.75±1.15 vs. 2.47±0.93, g=1.21 MT (VR vs. SA) 0.40±0.24 vs. 0.63±0.32, g=0.80 % of MT to PV (VR vs. SA) 24.14±14.09 vs. 34.72±19.59 MA (PA Vs. VR) 0.11±0.018 vs. 0.08±0.02, g=1.56 MA (PA vs. SA) 0.11±0.018 vs. 0.098±0.025, g=0.54 No differences found for MUs
King (1993)	Counterbalanced, repeated measures Hand therapy patients (n=146) M:F = 84:62 Age range: 16–78 years	PA: missile computer game where participant could use grip or pinch device to stop missiles Ex: squeeze the grip or pinch device	Number of repetitions Measured by a computer programme	Significant differences between the groups in favour of PA. Mean reps/3 minutes, PA vs Ex: Grippers 237.24±109.5 vs. 170.7±85.96, p<0.001, g= 0.67 Pinchers 240.5±101.51 vs. 203.2±98.16, p<0.05, g= 0.37

Study	Design and participants	Interventions	Outcomes	Results
Lin, Wu, and Trombly (1998)	Randomised, counterbalanced, repeated measures Healthy adults (n=24) M:F = 8:16 Mean age: 24 years	PA: reaching for and pressing the lever of a desk bell to make it ring SA: same task but bell did not ring. Control: reaching forwards and bisecting a line on a piece of paper	MT (sec) PV (mm/sec) % of MT at PV Measured by a three-camera motion capture system	Significant difference for MT and PV in favour of PA. PA vs. control: MT 0.71±0.13 vs. 0.78±0.21, g=0.39 PV 1259.2±199 vs. 1198.9±228.6, g=0.28 No difference for % of MT at PV
Ma, Trombly, and Robinson-Podolski (1999)	Healthy adults without experience using chopsticks (n=40) M:F = 12:28 Mean age: 24 years	PA: pick up and eat cheese with chopsticks. SA: pick up eraser and bring it to the mouth. Both conditions assessed during a learning phase and then as immediate motor performance 24 hours later	Successful completion of task MT (sec) D (mm) PV (mm/sec) Measured by three-camera motion capture	Success rate significantly greater in the PA group vs. SA group: 0.70±0.17 vs. 0.59±0.20, g=0.59. No differences in MT, PV, or D between the conditions
Miller and Nelson (1987)	Randomised, repeat measures Healthy adults (n=30) M:F = 0:30 Age not provided	PA: stirring a substance in a concealed bowl to make cookies. Vanilla added to mixture and fresh cookies in the oven to simulate baking environs. SA: as above but environment not augmented	Repetitions Duration of performance Manual counts of repetitions, stopwatch used for recording duration	Non-significant differences in favour of PA. PA vs. SA: Repetitions: 103.3±67.3 vs. 77.07±54.2, p=0.052, g=0.42 Duration: 233.4±169.3 vs. 141.07±87.4, g=0.67

Study	Design and participants	Interventions	Outcomes	Results
Morton, Barnett, and Hale (1992)	Randomised, repeated measures Healthy adults (n=30) M:F = 15:15 Mean age: 45 years	PA: pushing lever on a weight-box device to ring a bell Ex: pushing lever on weight-box (no bell)	Repetitions Duration of performance Manual counts of repetitions, stopwatch used for recording duration	No significant differences between PA and Ex groups for number of repetitions or duration. PA vs. Ex (means of 3 trials): Repetitions: 169.37±103.03 vs. 186.53±75.15, g=-0.19 Duration: 175.38±103.18 vs. 191.73±72.1, g=-0.15
Rice, Alaimo, and Cook (1999)	Randomised, counterbalanced, repeated measures Healthy adults (n=39) M:F = 0:39 Mean age: 30 years	PA: grasping a familiar labelled can of tomato soup from the bench and placing on a shelf SA: grasping and placing an unlabelled can of soup Ex: grasping and placing a lump of clay (weight and shape matched)	MT (secs) MUs D (degrees) Measured by an electrogoniometer placed on right elbow	Significantly fewer MUs (smoother movement) in the PA vs. Ex: 59.85±19.79 vs. 66.03±24.10, g=0.28 Significantly less D in SA vs. Ex: 492.42±151.11 vs. 526.61±99.01, g=0.27 No difference in MT between the groups

Study	Design and participants	Interventions	Outcomes	Results
Rice, Davies, and Maitra (2009)	Randomised, counterbalanced, repeated measures two-factor experiment with repeated measures on one factor Healthy adults (n=59) M:F = 12:28 Age range: 18–45 years	PA: opening a cupboard door, reaching for, and placing a cup on a shelf, immediate or prolonged exposure (transparent or opaque door) SA: as above with a lump of clay (shape and weight matched)	MT (secs) PV (mm/sec) MV (mm/s) % of MT to PV MUs D (mm) Measured by a four-camera motion capture system	No significant differences between PA and SA for immediate exposure condition When participants had prolonged visual exposure to objects there was faster movement, higher mean PV, quicker time to PV and fewer MUs PA vs. SA: MT 0.57± 0.24 vs. 0.64±0.21, g=0.31 MV 669.00±795.45 vs. 349.34±480.01, g=0.48 % of MT to PV 0.56±0.26 vs. 0.45±0.25, g=0.43 MUs 2.21±1.78 vs. 2.76±1.81, g=0.30
Rice and Renock (2006)	Randomised, counterbalanced, repeated measures Healthy adults (n=43) M:F = 0:43 Age range: 22–62 years	PA: reaching for a magazine in three different conditions; most preferred, neutrally preferred, or least preferred magazine	MT (sec) PV (degrees/sec) % of MT to PV MUs D (degrees) Measured by elbow electrogoniometer	No significant differences on any DV excepting slower MT, and greater MUs, for neutrally preferred vs. least preferred magazines: MT 1.31±0.95 vs. 0.95±0.43, g=-0.43 MU 9.09±6.72 vs. 6.40±3.65, g=0.56

Study	Design and participants	Interventions	Outcomes	Results
Ross and Nelson (2000)	Randomised, counterbalanced, repeated measures Healthy adults (n=60) M:F = 0:60 Mean age: 22 years	PA: pick up pencil and prepare to write name in normal manner SA: pretend to pick up a pencil and prepare to write name Ex: reaching forward movement in equidistance and height as PA condition	RT (sec) MT (sec) MUs D (cm) PV (cm/sec) % of MT to PV EV (cm/sec) Measured by four-camera motion capture system	Significantly better outcomes in PA than SA or Ex for all DVs (faster RT and MT, fewer MUs, lower D, PV and EV) For PA vs. Ex conditions: RT 0.416±0.11 vs. 0.429±0.11, g=0.12 MT 0.526±0.08 vs. 0.550±0.14, g=0.21 MUs 1.10±0.24 vs. 1.26±0.35, g=0.53 D. 43.5±4.7 vs. 48.4±6.7, g=0.84 PV 113.7±17.0 vs. 123.0±17.7, g=0.53 % of MT to PV 0.579±0.08 vs. 0.647±0.11, g=0.70 EV 55.5±12.8 vs. 81.1±22.9, g=1.37
Sackaloo, Strouse, and Rice (2015)	Randomised, counterbalanced, repeated measures Healthy adults (n=40) Mean age: 23 years Gender not reported	PA: reaching for seven different types of candy ranked by participants from most to least preferred (three conditions: most, neutral and least preferred) Candy placed in front of participant; candy reached for, grasped, and brought back to a marked position on table	MT (sec) PV (mm/sec) % of MT to PV MUs Measured by a four-camera motion capture system	Significantly faster movement time, and fewer MUs, in the most preferred vs. least preferred conditions MT 0.73±0.26 vs. 0.82±0.23, , p=0.003, g=0.36 MUs 2.89±2.80 vs. 3.77±2.00, p=0.001, g=0.36 No significant differences for PV and time to PV between most, neutral or least preferred conditions

Study	Design and participants	Interventions	Outcomes	Results
Steinbeck (1986)	Randomised, counterbalanced, repeated measures Healthy adults (n=30) M:F = 15:15 Mean age: 19 years	PA: ping-pong game; squeezing rubber bulb to above specified track Ex: squeezing a rubber ball for ex (no game) Both conditions performed to perceived point of 'working somewhat hard'	Number of repetitions Manual count of repetitions	Significantly greater number of repetitions in the PA vs. Ex groups: 105.67±33.55 vs. 95.50±32.45, p=0.05, g=0.30
Taylor, Kedgley, Humphries, and Shaheen (2018)	Randomised, counterbalanced, repeated measures Healthy adults (n=14) M:F = 8:0 Mean age: 22 years	PA: five purposeful activities (washing armpit, eating, combing hair, retrieving bottle from a shelf, perineal care) SA: performing the equivalent activities as a movement (e.g., touching contralateral armpit, touching the mouth or back of head)	Maximum and minimum joint ROM (°) Joint angles (°) Movement patterns (mean° from 0 to 100% of movement cycle for each task) Movement variability (°) Measured by an 11-camera motion capture system	Thoracic ROMs were significantly greater in PA vs. SA. Shoulder elevation and internal/external rotation for perineal care 90° vs. 79° and 77° vs. 63° respectively; shoulder elevation 81° vs. 68° for combing hair, and 129° vs. 107° for retrieving object from shelf. Forearm rotation showed no differences between either condition for any task. Wrist ROMs were greater for PA vs. SA for all tasks, except washing armpit. Few differences in intra-subject movement variability between conditions

Study	Design and participants	Interventions	Outcomes	Results
Wagner, Krauss, and Horowitz (1995)	Randomised, repeated measures Healthy adults (n=45) M:F = 45:0 Mean age: 25 years	PA: moving a cork ball on a board using air squeezed from a rubber bulb as a game for 2 minutes with another person present. Ex (2 conditions): squeeze a rubber bulb as ex for 2 minutes, with another person present or alone	Number of repetitions Manual count of repetitions	Significantly greater repetitions in favour of Ex. PA vs. Ex: 270.13±61.15 vs. 341.53± 53.83, g=-1.23
Wu, Trombly, Lin, and Tickle-Degnen (1998)	Randomised, counterbalanced, repeat measures Healthy participants (n=25) (14 stroke; results not reported here) M:F = 6:17 Mean age: 63 years	PA: reaching forward and pushing down on a handle to chop a fresh mushroom SA: reaching forward and pushing down on a concealed handle (no mushroom)	MT D PV Percentage of MT at PV MUs Measured by a two-camera motion capture system	Findings were non-significant or not in support of PA vs SA: MT 0.51±0.13 vs. 0.47±0.10, g=-0.34 D 398.59±52.72, vs.387.62±44.4, g=-0.22 PV 1260.79±304.64 vs. 1272.18±290.38, g=0.04 % of MT at PV 42.35±7.67 vs. 44.53±7.27, g=0.29 MUs 0.73±0.22 vs. 0.72±0.24, g=-0.04

Study	Design and participants	Interventions	Outcomes	Results
Wu, Trombly, and Lin (1994)	Randomised, counterbalanced, repeated measures Healthy physiotherapy or biomedical students (n=37) M:F = 0:37 Mean age: 21 years	PA: pick up a pencil from a pencil holder and prepare to write name SA: pick up an imaginary pencil and pretend to prepare to write name Ex: reach forward movement in equidistance and height as PA	RT (sec) MT (sec) MUs D (cm) PV (mm/sec) Percentage of MT at PV Measured by a three-camera motion capture system	Significant differences in favour of PA for RT, MT, MUs and D PA. vs Ex: RT 0.391±0.068 vs. 0.434±0.075, g=0.59 MT 0.976±0.154 vs. 1.062±0.161, g=0.54 MUs 0.891±0.405 vs. 1.292±0.446, g=0.93 D 41.331±5.556 vs. 47.551±7.679, g=0.92 PV and % of MT at PV were lower in the PA vs. Ex condition: PV 1214.332±505.968 vs. 1610.311±963.354, g=0.51 % of MT at PV 58.42±16.15 vs. 66.79±20.72, g=0.45

Note. Values are mean ± *SD* or as otherwise indicated. The statistic *g* refers to Hedges *g* for effect size, where 0.2 = small effect, 0.5 = medium effect, 0.8 = large effect and were calculated on the difference between condition or group.

M = male; F = female; PA = purposeful activity; SA = simulated activity; MT = movement time; PV = peak velocity; MU = movement unit; D = displacement; VR = virtual reality; MA = maximum aperture; Ex =exercise; MV = mean velocity; DV = dependent variable; RT = reaction time; EV = end velocity; ROM = range of movement.

4.2.5 Discussion

This review was conducted to identify the influence of engaging in purposeful activities and occupations on upper extremity motor performance in healthy and musculoskeletal injury populations. The results provided evidence that purposeful activities had a beneficial effect on the quality and quantity of movement in healthy populations, distinct from simulated tasks, exercise repetitions or movement performed under artificial conditions. The findings suggested that when a person engaged in an activity or occupation equal or similar to that in everyday life, they were likely to perform more repetitions for longer periods of time. In addition, movement was more likely to be smoother, more controlled and performed more quickly. The findings of this review concur with results from reviews in predominantly neurological populations (Hétu & Mercier, 2012; Lin et al., 1997), that also found enhanced motor performance for movement embedded in familiar activities as opposed to arbitrary motion.

The body of evidence in this review was drawn from studies of moderate quality and conducted mainly in healthy populations. There was a paucity of research on the influence of purposeful activities in individuals with musculoskeletal injuries. Despite an extensive search, only one study (King, 1993) was located that included individuals with a musculoskeletal condition or injury. In that study King (1993) demonstrated significantly greater movement quantity in the activity group, but the study was of very low quality. Caution must be applied in generalising the results from that study, as King did not report on the nature or characteristics of the participant's injuries. With respect to the quality of the studies in the review, concerns were noted with recruitment, reporting, blinding, validity of outcome measures and statistical analyses that did not consider covariates. There was an overrepresentation of young participants, females, and students, making generalisability to other healthy populations such as older adults or manual workers, difficult. Manual counting was used in six of the seven studies that measured repetitions (Bakshi et al., 1991; Hoppe et al., 2008; Miller & Nelson, 1987; Morton et al., 1992; Steinbeck, 1986; Wagner et al., 1995), leading to potentially inaccurate counting or inconsistencies in what constituted a repetition. Lack of study rigour indicated that the findings be interpreted with caution and highlighted a need for replication of this type of research in individuals with upper extremity injury.

Purposeful activities and occupations

A premise under investigation in this review is that purposeful activities and occupations elicit motor performance measurably different from non-purposeful tasks or rote exercises. The purpose and meaning ascribed to activities and occupations is complex (Eakman et al., 2010), and was not evaluated in any of the studies. The degree to which the activities or occupations held purpose or meaning for participants was therefore unknown. Many of the activities in the studies could be considered repetitious and purposeless, such as ringing a bell, or placing a can or mug onto a shelf (Holubar & Rice, 2006; Lin et al., 1998; Rice et al., 1999). Even in the study by Bakshi and colleagues (1991) where activities were self-selected, choice was limited to eight activities and their perceived value was unknown. If an activity lacks value, an individual may not persevere for as long, put in equal amounts of effort or attend to the task with the same degree of focus, potentially lowering the quality and quantity of the movement produced. In future, research that evaluates movement during the performance of activities or occupations, it is recommended that the activities are: i) self-selected; ii) performed in a naturalistic manner; iii) conducted in the participants' own environment; and iv) evaluated for meaning using tools designed for that purpose such as the Occupational Value-9 (Persson & Erlandsson, 2010), or the Meaningful Activity Participation Assessment (Eakman et al., 2010).

Several studies investigated the relative effect that objects and materials have on motor performance during an occupation (Holubar & Rice, 2006; Rice & Renock, 2006; Sackaloo et al., 2015). In those studies, movement speed and smoothness were enhanced in participants who reached for a personally owned or preferred object. This premise has been corroborated by Hétu and Mercier (2012), who found that adding an object to a motor task enhanced quality of movement. The results suggest that clinicians may be able to enhance motor performance by having patients use their own materials and objects during therapy, for example, by putting on items of clothing or playing a preferred game. Therapists could observe movement during performance of purposeful activities and modify the activity or movement parameter to achieve the desired motor outcome.

Motor performance outcomes

Motor performance outcomes varied across studies, and none were measured by all authors. With respect to quantity or dosage of motion, small to medium effects were observed for purposeful activities and occupations. For the most part, participants performed more repetitions and for longer periods of time, when performing purposeful activities. In studies where duration of performance was foreshortened, it is possible that the activity itself was insufficiently motivating to persevere for longer. As an example, the activity in the study by Morton et al. (1992) involved the pushing of a lever in a weight box apparatus, either to ring a bell (activity with purpose) or as exercise (without purpose). Although participants in the purpose group found the bell-ringing fun, this did not result in longer duration of performance compared with the group who had no bell. The nature of activities and occupations are that they involve purpose, meaning and occur within the context of daily life (Molineux, 2010). The activity in Morton's study did not relate to any purposeful end goal, lacked meaning, and was performed in an artificial research environment, and these factors may have accounted for the lack of perseverance observed in both groups. The study by Taylor et al. (2018) was the only study to evaluate range of motion during the performance of functional tasks. Those authors showed that participants used greater arcs, and therefore higher overall volume of motion, when performing tasks in a naturalistic manner rather than as simulated motions.

The findings of enhanced movement quantity demonstrate opportunity for therapists to use purposeful activities in more strategic ways. Wrist and finger stiffness is a common complication after injury, and occurs, for example, in up to 20% of patients with surgery of distal radial fracture (Egol et al., 2014). Range of movement exercises are used to promote movement, but have variable rates of adherence and may not achieve the desired dosage of motion (Bassett, 2003). The findings from this review can only be applied to healthy participants but point to the potential of purposeful activities and occupations in augmenting the amount of movement volume.

Quality of motion was evaluated by a range of kinematic variables where faster reaction and movement times, higher peak velocity, less displacement and fewer movement units indicate greater movement efficiently and control (Kehoe & Rice, 2016). Reaction and movement times were faster during purposeful activity conditions in the majority of studies that measured those outcomes. Although the magnitude of effect was predominantly small to medium, this may indicate that the familiarity of movement during purposeful activities requires less focus and attention than non-purposeful tasks. A large effect for purposeful activity on movement time was found by Fasoli et al. (2002), but as the study only sampled five participants this may represent an inflated effect size. Velocity metrics included peak velocity and percentage of movement time to peak velocity. Significant differences were found in a majority of studies. In most cases, higher peak velocity was assumed to represent greater movement efficiency and skill (Kehoe & Rice, 2016; Lin et al., 1998). The opposite was hypothesised in some cases, in that movement executed more slowly with lower peak velocity allowed for greater control and was an indication of more skilled motion (Fasoli et al., 2002; Hall & Nelson, 1998). The differing outcomes for peak velocity may be related to the differing demands of the task (e.g., throwing a dart vs. slicing bread), where one task inherently requires greater speed over another. This highlights the need to further evaluate the differential effect of various activities and occupations on motor performance metrics.

Smoothness and coordination were measured by the number of times that acceleration and deceleration occurred in succession during a movement (movement units) (Rice & Renock, 2006). Generally, fewer movement units are associated with smoother motion (Holubar & Rice, 2006). In this review, a majority of studies found fewer movement units when participants were engaged in a purposeful activity, particularly where familiar or preferred objects were used. The estimated effects were generally small to medium, but if a similar finding were established in clinical populations, purposeful activities have potential for helping to restore smooth, dextrous motion after injury.

Limitations and future directions

This review brought together a body of work that has not previously been examined in the musculoskeletal field. Although a large number of studies were identified, the difficulty of locating all studies must be acknowledged due to the range of terms used for occupation, particularly in older studies. Other limitations of this review include only one reviewer screening the titles and abstracts during the initial screening phase, and the inclusion of only one study in a population with musculoskeletal injury. The applications of the findings to clinical practice must therefore be regarded as suggestions only. The findings nonetheless represent best available evidence at this time and highlight the need for further research in clinical populations.

Future research should investigate the influence of activities and occupations in upper extremity pathologies and in isolated joints of the upper extremity. Activities and occupations investigated should be those selected by participants as having meaning and purpose. Researchers are challenged to conduct investigations in the environments in which participants perform daily occupations. This is becoming increasingly possible with advances in wearable technologies and field motion capture systems. Evaluating discrete activities and occupations linked to specified motor performance impairments will help to elucidate which occupations can be used to target identified problems, for example, loss of finger dexterity, wrist extension loss or difficulties with initiating finger flexion.

4.2.6 Conclusion

This review found evidence from multiple randomised studies that for healthy adults, engagement in purposeful activities will generally result in greater quantity and quality of movement than simulated activities or movement performed without purpose. Occupation-based interventions are increasingly being advocated in the musculoskeletal literature for treating motor impairments, yet the mechanisms by which they operate are not well-understood. This review adds evidence to the premise that purposeful activities elicit movement in measurably different ways from non-purposeful tasks. Investigating the mechanisms of action of purposeful activities and occupations after upper extremity injuries would elucidate whether motor performance is influenced similarly in injured individuals. These data would provide a robust foundation on which to develop interventions based on the strengths of movement embedded in purposeful activities and occupations.

4.3 Chapter summary

The systematic review presented in this chapter showed that there are discernible differences in the way movement is performed when people are performing an activity that has purpose versus no perceived purpose. Because of the lack of studies in upper limb injuries the review was unable to determine whether the findings hold true for people with wrist injury, particularly early after injury or surgery. There is a suggestion that people might achieve more movement if they embed movement into daily activities, rather than solely performing exercise routines. This suggestion showed that primary research into the influence of activity performance on wrist movement in clinical populations was warranted.

The review highlighted several methodological concerns with the included studies that informed the development of subsequent studies in this thesis. The primary concerns were the lack of self-selection of valued activities and the location of data collection in laboratory or clinical settings. Both these factors may have affected motor performance during purposeful activities. For activities to be used as a therapeutic tool the activities must be meaningful and purposeful, and be performed in context where they would usually occur (Hinojosa & Blount, 2014b). To address those concerns, it was determined that studies III and IV would be conducted in the homes of participants using activities chosen by participants.

Before embarking on primary research, I first needed to understand whether it was feasible and safe to use daily activities as a rehabilitative strategy. A second systematic review was therefore planned to investigate the use and safety of daily activities during the early weeks of rehabilitation.

Chapter 5 Published study II: A systematic review of how daily activities and exercises are recommended following volar plating of distal radius fractures and the efficacy and safety of early versus late mobilisation

5.1 Chapter overview

This chapter presents the second systematic review undertaken (study II). The objective of the review was to critically examine the literature on how performance of daily activities is recommended in early mobilisation protocols. I wanted to determine whether daily activities are considered safe and explore the benefits of early mobilisation that specified use of daily activities. Exercise routines are a well-established approach to rehabilitation of wrist and hand fractures in the immediate weeks following surgery, but it was not clear whether performance of daily activities was commonly recommended. Clinical practice suggested wide variability in advice given to patients on daily activities so establishing and evaluating current practice from the literature was seen to be an important early step in this thesis.

Chapter 5 addresses RQ2: How is activity recommended following surgical treatment of distal radius fractures and what is the efficacy and safety of early versus delayed mobilisation?

The manuscript was published in Hand Therapy (Collis et al., 2020a). The full citation for the article is:

Collis, J. M., Signal, N., Mayland, E., & Wright-St Clair, V. A. (2020). Influence of purposeful activities on upper extremity motor performance: A systematic review. *OTJR: Occupation, Participation and Health, 40*, 223-234. https://doi.org/10.1177/1758998320967032

The manuscript is included here with citations, figures and tables formatted consistent with the thesis. A copy of the published article is found in Appendix B.

5.2 Published article

5.2.1 Abstract

Introduction

Following surgical repair of distal radius fractures, mobilisation timeframes and interventions vary. Early mobilisation (<2 weeks postoperatively) usually includes range of motion exercises and may include recommendations to perform daily activities. The review investigated (i) how early mobilisation was recommended, particularly with respect to wrist use during daily activities and (ii) the efficacy and safety of early versus delayed mobilisation (< or ≥ 2 weeks).

Methods

The study protocol was registered on PROSPERO (CRD42019136490). Five databases were searched for studies that compared early and delayed mobilisation in adults with volar plating of distal radius fractures. The Downs and Black Quality Index and the Template for Intervention Description and Replication checklist were used for quality evaluation. Effect sizes were calculated for range of movement, function, and pain at 6–8, 10–12 and 26 weeks. A descriptive analysis of outcomes and mobilisation regimes was conducted.

Results

Eight studies with a mean Quality Index score of 20 out of 28 (SD=5.6) were included. Performing daily activities was commonly recommended as part of early mobilisation. Commencing mobilisation prior to two weeks resulted in greater range of movement, function, and less pain at up to eight weeks postoperatively than delaying mobilisation until two weeks or later.

Discussion

Performance of daily activities was used alongside exercise to promote recovery but without clearly specifying the type, duration, or intensity of activities. In combination with exercise, early daily activity was safe and beneficial. Performing daily activities may have discrete advantages. Hand therapists are challenged to incorporate activity-approaches into early mobilisation regimes.

5.2.2 Introduction

Following surgical treatment of distal radius fracture it is common practice to commence mobilisation of the wrist within two weeks of surgery (Ikpeze et al., 2016). Delaying movement for longer than two weeks has been associated with greater wrist stiffness and poorer outcomes (Dennison et al., 2020). Wrist mobilisation following surgical distal radius fracture repair is predominantly facilitated by active range of motion (ROM) exercises, but may also be promoted through the performance of daily activities when a splint is removed (Naughton & Algar, 2021). Engaging in daily activities within the first two weeks of rehabilitation may be advantageous in promoting use of familiar movement patterns, building self-efficacy, augmenting movement volume, mitigation of pain, and facilitating engagement in therapy (Colaianni & Provident, 2010; Guzelkucuk et al., 2007; Mehta et al., 2011) and may be equally effective as exercise routines (Quadlbauer et al., 2020). While therapeutic exercise for early mobilisation following surgical repair of distal radius fracture is widely practiced (Quadlbauer et al., 2020; Smith et al., 2004), the safety and benefit of including daily activities in the first two weeks of postoperative rehabilitation has not been established.

Hand therapists are increasingly being challenged to use activity and occupation-based interventions in clinical practice to facilitate more holistic, patient-focused therapy (Colaianni & Provident, 2010; Weinstock-Zlotnick & Mehta, 2018), but evidence is lacking to support the safety of daily activities after surgical repair of distal radius fracture. Additionally, while activity in early mobilisation regimes is frequently alluded to in the literature, it is often poorly defined and may be overlooked as an independent therapeutic intervention (Michlovitz et al., 2004). As it is often not included in the description of post-operative regimes, but may be used in clinical practice, it is possible that early activity following surgical treatment of distal radius fractures has greater benefit than is currently understood. The lack of reporting hinders therapeutic use of evidence-based safe activity and may result in inconsistent advice on activity performance for patients in the early postoperative period. It may also lead to conservative approaches that delays performance of daily activities until two weeks or later, due to safety concerns.

The review therefore had two aims. The first objective was to explore how mobilisation, in particular performance of daily activities without a splint, was recommended following volar plating of distal radius fractures in early mobilisation regimes. The second objective was to evaluate the efficacy and safety of early versus delayed mobilisation. Efficacy was evaluated by determining whether there was greater wrist and forearm movement, better self-reported function and lower pain in early mobilised groups compared with delayed mobilisation. Safety was defined as adverse events occurring at equal or lower rates in early mobilisation regimes when compared with delayed mobilisation.

5.2.3 Methods

A systematic review was undertaken following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) recommendations (Moher et al., 2015). The study protocol was registered on PROSPERO (CRD42019136490). In March 2020, the primary author (JC) searched CINAHL Complete, MEDLINE and SPORTDiscus (via EBSCOhost), and Emcare and AMED (via Ovid) to identify relevant studies. The full electronic search strategy for MEDLINE is in Supplementary File 1 (Appendix C). Comparative studies that evaluated the outcomes of early and delayed mobilisation were included. Only fractures treated with volar plates were included because of the more complex nature of dorsal plate treatment (Ikpeze et al., 2016). Publication date was after the year 2000 to reflect the timeframe when volar plating became common practice. Case series were excluded due to large numbers of surgical studies providing minimal details on postoperative regimes and because they did not directly evaluate postoperative management. There is no accepted timeframe for delineating early and delayed mobilisation. It was defined in the review as occurring prior to or later than two weeks postoperatively. The timeframe was set to reflect clinical practice where mobilisation often commences at the first postoperative appointment. Mobilisation regimes were those that used ROM exercises and may or may not have included the performance of daily activities without a splint. Activity was defined as purposeful actions and sets of tasks performed by individuals on a day to day basis (Amini et al., 2014; Polatajko et al., 2004). They denote purpose and meaning, and when grouped together constitute the broader occupations of work, play, leisure, daily living activities and social participation (Amini et al., 2014). Full eligibility criteria are listed in Table 5. Search results from each database were exported to EndNote™ X8, citations combined, and duplicates removed. Titles and abstracts were reviewed to remove studies not meeting inclusion criteria. Full texts of remaining articles were screened for inclusion. Reference lists of systematic reviews and included studies were searched for missed studies.

Table 5

Inclusion and exclusion search criteria

Inclusion criteria:
Adults aged ≥ 18 years
Volar plating of a distal radial fracture
Randomised controlled trial or comparative observational study
Mobilisation within two weeks of surgery
Compared with mobilisation delayed until two weeks or later
Published after 2000
Exclusion criteria:
Systematic or narrative reviews, case series, position papers

Data extraction

The following data were extracted from the included studies by the primary author (JC) based on criteria agreed between authors: author, date, study design, fracture type and participant characteristics. Intervention data extracted were exercise types, splint use and performance of daily activities (timeframes, types, intensity, therapeutic use). Further information on postoperative interventions was requested from authors of all studies, particularly to clarify instructions given about daily activities. Additional information was received from five authors (Andrade-Silva et al., 2018; Clementsen et al., 2019; Lozano-Calderón et al., 2008; Valdes, 2009; Watson, Martin, et al., 2018) and there was no reply from three (Duprat et al., 2018; Iitsuka et al., 2016; Quadlbauer et al., 2017). Activity and exercise data were tabulated and reported descriptively. Outcome data were ROM, function, pain, and adverse events. Outcomes were grouped into 6-8, 10-12 and 24-26 weeks to facilitate comparisons across studies. Outcome data were reported as group means and standard deviations. Effect sizes were calculated for the outcomes of wrist extension and flexion, pronation and supination, Disabilities of the Arm, Shoulder and Hand (DASH) or the Patient Rated Wrist Evaluation (PRWE) and pain, on the difference between groups, according to Hedges g, where 0.2, 0.5 and 0.8 indicates a small, medium and large effect respectively (Cooper et al., 2019). Estimation of standard deviations was conducted if not provided (Wan et al., 2014). Meta-analyses could not be conducted because, although all studies compared early and delayed mobilisation, there were insufficient high quality studies with equivalent purpose, design, and outcomes at equivalent follow-up timeframes.

Assessment of methodological quality

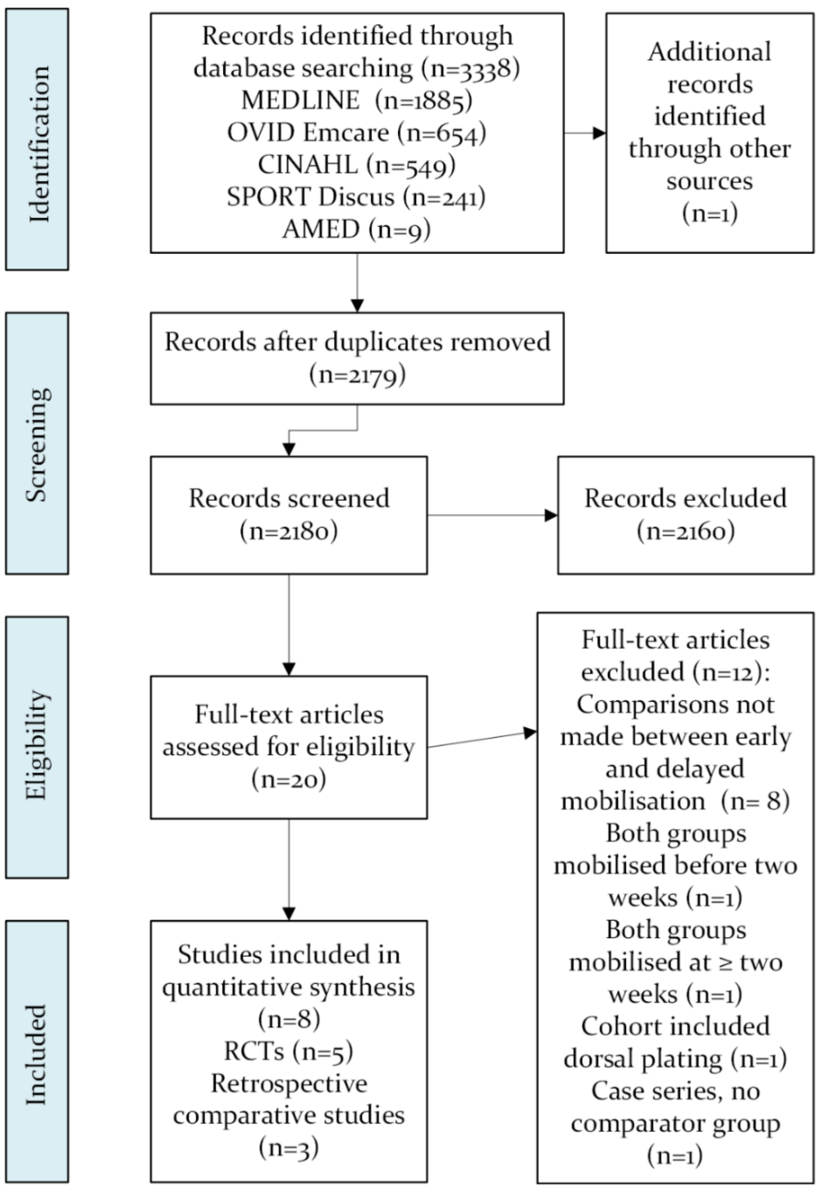
Risk of bias was assessed at the study level using the validated Downs and Black Quality Index (Downs & Black, 1998) by two authors (JC and NS). The index evaluates methodological study quality and is suitable for randomised and observational studies. The final score, out of 28 points, was assigned one of four grades, in line with previous reviews, to give an overall rating: 'excellent' for 26-28 points, 'good' for 20-25 points, 'fair' for 15-19 points and 'poor' for ≤14 points (Chudyk et al., 2009). Where items were scored differently consensus was reached through discussion. A level of evidence was assigned to each study according to the Oxford Centre for Evidence-Based Medicine (CEBM) 2011 Levels of Evidence (Howick et al., 2011) by (JC). The quality of postoperative intervention reporting was evaluated by the Template for Intervention Description and Replication (TIDieR) checklist (Hoffmann et al., 2014). The TIDieR was developed in 2014, as an extension to the CONSORT 2010 (Moher et al.) and SPIRIT 2013 (Chan et al.) statements (Hoffmann et al., 2014) to evaluate and promote better reporting of interventions. For each item the article was scored as not reported (0), partially reported (1), and adequately reported (2), according to the method described by Yamato et al. (2018). A summary score ranging from 0 (poor reporting) to 24 (good reporting) was assigned.

5.2.4 Results

The study selection process is detailed in Figure 7. Following duplicate removal, 2179 articles were located across five databases. An additional article was found by searching reference lists. The titles and abstracts of 2180 articles were screened by a single author (JC). Twenty articles were identified for full-text review, of which eight were included in the final review.

Figure 7

PRISMA Flow diagram



Description of studies

Study design and participant characteristics are detailed in Table 6. A total of 519 participants were included across eight studies. The largest trial randomised 133 participants across three groups (Watson, Haines, et al., 2018) and the smallest cohort had 23 participants (Valdes, 2009). There was a majority of females (72%), with a mean age range across all participants of 48 to 63 years. Two studies included only AO (Fernandez, 2001) type A fractures; in the remaining six studies 72% had AO types B or C. Across all 519 participants 52% had AO type B or C fractures. Of the eight included studies, five were level II Oxford CEBM levels of evidence (Howick et al., 2011) randomised controlled trials (RCTs) (Andrade-Silva et al., 2018; Clementsen et al., 2019; Lozano-Calderón et al., 2008; Quadlbauer et al., 2017; Watson, Haines, et al., 2018) with the remaining three being level four retrospective chart reviews (Duprat et al., 2018; Iitsuka et al., 2016; Valdes, 2009). The studies all compared early and delayed mobilisation (< or ≥ two weeks) but varied with respect to purpose. Four studies aimed to determine the optimal period of immobilisation (Duprat et al., 2018; Lozano-Calderón et al., 2008; Quadlbauer et al., 2017; Watson, Haines, et al., 2018). The purpose of the remaining studies was to evaluate use of analgesia (Andrade-Silva et al., 2018), compare home and outpatient rehabilitation (Clementsen et al., 2019), achievement of minimal clinically important differences for the DASH score (Iitsuka et al., 2016), or compare numbers of hand therapy appointments (Valdes, 2009). In the early groups, mobilisation was commenced at an average of 4 days (range 1-8) and delayed until an average of 30 days (weeks two(Andrade-Silva et al., 2018; Clementsen et al., 2019; Duprat et al., 2018; Iitsuka et al., 2016), three(Watson, Haines, et al., 2018), five(Quadlbauer et al., 2017) or six(Lozano-Calderón et al., 2008; Valdes, 2009; Watson, Haines, et al., 2018)), in the immobilised groups (see Table 7).

Performance of daily activities in early mobilised groups

The activity interventions are detailed in Table 7. In all studies, daily activities were advocated, without a splint, from the time of mobilisation. Duprat et al. (2018) did not describe daily activity performance but because a splint was not given it is assumed participants were free to use the wrist. Iitsuka et al. (2016) also did not describe splint use or daily activities but the paper implied non-splint use. The types and intensity of activities lacked detail and were described in broad terms such as light activities, hygiene, eating, dressing, showering, or lifting less than 2kgs. No study investigated activity-based interventions as an independent variable. Two studies reported an approach where activities were used for the purpose of exercising the wrist (Lozano-Calderón et al., 2008; Watson, Haines, et al., 2018). Of note, Watson, Haines, et al. (2018) took a collaborative approach, agreeing on activities that promoted wrist movement and those that were enjoyed where possible.

Table 6

Characteristics and main outcomes of the included studies in order of quality

Author	Level of evidence[i] Study Design Quality of evidence[ii]	Study purpose	AO classification (type A, B or C) [iii]	Characteristics	Outcomes	Effect sizes at 6-8 weeks, EM vs. DM	Effect sizes at 10-12 weeks, EM vs. DM	Effect sizes at 26 weeks, EM vs. DM
Watson, Haines, et al. (2018)	Level 2 RCT Quality of evidence: Excellent	Compared (a) one week, (b) three weeks and (c) six weeks immobilisation	A: 12% B: 67% C: 18% Unknown: 3%	Total n = 133 (a) n=46 Mean age 54.0±15.6 Female: 63% DHI: 41% (b) n = 41 Mean age 51.1±14.9 Female: 75.6% DHI: 29% (c) n = 46 Mean age: 52.0±15.9 Female: 54% DHI: 39%	Data for 1 vs 6 weeks immobilisation:			
					Wrist extension	Medium	NR	Small
					Wrist flexion	Large	NR	None
					Supination	Small	NR	None
					Pronation	Small	NR	None
					DASH	Medium	NR	None
					PRWE	Medium	NR	None
					Pain: NRS-11	None	NR	Small

Author	Level of evidence[i] Study Design Quality of evidence[ii]	Study purpose	AO classification (type A, B or C) [iii]	Characteristics	Outcomes	Effect sizes at 6-8 weeks, EM vs. DM	Effect sizes at 10-12 weeks, EM vs. DM	Effect sizes at 26 weeks, EM vs. DM
Clementsen et al. (2019)	Level 2 RCT Quality of evidence: Good	Compared (a) EM (2-3 days) and fortnightly physiotherapy with (b) 2 weeks immobilisation and a single physiotherapy visit and exercise programme	A: 100%	Total n = 119 (a) n =57 Mean age: 55±12.4 Female: 93% DHI: 49% (b) n = 62 Mean age: 55±11.9 Female: 89% DHI: 53%	Wrist extension Wrist flexion Supination Pronation Quick DASH PRWE Pain: VAS	Small None Small Small Small Small Small	None None None None None None None	NR NR NR NR NR NR NR
Andrade-Silva et al. (2018)	Level 2 RCT Quality of evidence: Good	Compared (a) EM (immediate, no splint) with (b) immobilisation in a splint for two weeks	A: 0% B: 1% C: 97%	Total n = 39 (a) n =19 Mean age: 51.2±16.6 Female: 58% DHI: 47% (b) n = 20 Mean age: 47.6±15.1 Female: 55% DHI: 60%	Wrist extension and flexion arc Supination & pronation arc Quick DASH, Pain: NRS-11	None Small None Small	None None Medium Medium	None Small Small Small

Author	Level of evidence[i] Study Design Quality of evidence[ii]	Study purpose	AO classification (type A, B or C) [iii]	Characteristics	Outcomes	Effect sizes at 6-8 weeks, EM vs. DM	Effect sizes at 10-12 weeks, EM vs. DM	Effect sizes at 26 weeks, EM vs. DM
Lozano-Calderón et al. (2008)	Level 2 RCT Quality of evidence: Good	Compared (a) EM (< 14 days) with (b) six weeks immobilisation	A: 38% B: 13% C: 48%	Total n=60 (a) n =30 Mean age: 55 Female: 63%, (b) n = 30 Mean age: 51 Female: 67%,	Wrist extension Wrist flexion Supination Pronation Quick DASH, Pain: NRS-11	NR NR NR NR NR NR	None None Small None None None	Small None None None None Small
Quadlbauer et al. (2017)	Level 2 RCT Quality of evidence: Fair	Compared (a) EM (immediate) with (b) five weeks immobilisation	A: 3.5% B: 3.5% C: 93%	Total n=28 (a) n =15 Mean age: 49.13±15.41 Female: 63% DHI: 53% (b) n = 13 Mean age: 58.77±12.06 Female: 67% DHI: 46%	Wrist extension Wrist flexion Supination Pronation Quick DASH PRWE Pain: NRS-11	Large Large Medium Medium Large Large Small	Medium Medium None None Medium Small Small	Large Large Medium None Medium Medium Small

Author	Level of evidence[i] Study Design Quality of evidence[ii]	Study purpose	AO classification (type A, B or C) [iii]	Characteristics	Outcomes	Effect sizes at 6-8 weeks, EM vs. DM	Effect sizes at 10-12 weeks, EM vs. DM	Effect sizes at 26 weeks, EM vs. DM
(Valdes, 2009)	Level 4 Retrospective chart review Quality of evidence: Fair	Compared (a) EM (at one week) with (b) six weeks immobilisation	Type A: 100%[iv]	Total n=23 (a) n =14 Mean age: 62.79±12.10 Female: 78% DHI: 28% (b) n = 9 Mean age: 55.22±12.54 Female: 67% DHI: 67%	Data for 1 vs 6 weeks immobilisation:	(at start of hand therapy 1 or 6 weeks)	(at discharge: mean 5 weeks for EM, 10 weeks for DM)	
					Wrist TAM	Small	Small	
					Forearm TAM	Small	Small	
					ULFI:	Small	Small	
					No. of therapy visits to reach 40º wrist extension and flexion		Large	
					No. of days to reach 40º wrist extension and flexion		Large	

Author	Level of evidence[i] Study Design Quality of evidence[ii]	Study purpose	AO classification (type A, B or C) [iii]	Characteristics	Outcomes	Effect sizes at 6-8 weeks, EM vs. DM	Effect sizes at 10-12 weeks, EM vs. DM	Effect sizes at 26 weeks, EM vs. DM
(Duprat et al., 2018)	Level 4 Retrospective chart review Quality of evidence: Fair	Compared (a) EM (immediate, no splint) with (b) immobilisation in a splint for 2 weeks	A: 54% B: 1% C: 45%	Total n=72 (a) n =36 Mean age: 61±17.4 Female: 69%, (b) n = 36 Mean age: 58 ±14.7 Female: 80%	Wrist extension Wrist flexion Supination Pronation Quick DASH PRWE Pain: VAS	NR NR NR NR NR NR NR	None Medium Small None None None Small	NR NR NR NR NR NR NR
(Iitsuka et al., 2016)	Level 4 Retrospective chart review Quality of evidence:	Compared MCID for function for (a) EM (< day 3) with (b) immobilisation for 2 weeks	A: 20% B: 9% C: 71%	Total n = 45 (a) n =27 Mean age: 57±13 Female: 74% DHI: NR (b) n = 18 Mean age: 49±19 Female: 56% DHI: NR	Data for group where there was a MCID for DASH: Wrist extension Wrist flexion Supination Pronation Quick DASH Pain: VAS	 Small None Small None Small NR	 None None Small Small Medium NR	 NR NR NR NR NR NR

Values are mean ± SD or as otherwise indicated i Level of evidence according to the Oxford Centre for Evidence-Based Medicine (CEBM) 2011 Levels of Evidence (Howick et al., 2011)

ii Quality of evidence according to the Downs and Black Quality Index (Downs & Black, 1998)

iii Type A: extra-articular; Type B: partial articular; Type C: complete articular (Fernandez, 2001)

iv AO classification was applied

AROM: active range of movement; DASH: disabilities of the arm shoulder and hand; DHI: dominant hand injured; DM: delayed mobilisation EM: early mobilisation; MCID: minimal clinically important difference NR: not reported; NRS: numeric rating scale; PRWE: patient rated wrist evaluation; RCT: randomised controlled trial; ROM: range of movement; ULFI: upper limb functional index; VAS: visual analogue scale

Table 7

Description of postoperative interventions for early mobilisation (EM) groups

Author	EM: mean no. of days surgery to mobilisation	DM: mean no. of days surgery to mobilisation	Exercise intervention	Removable splint provided when mobilised	Daily activities performed without splint	Activity types	Intensity	Therapeutic use[1]
Watson et al. [21]	7	21	Standardised wrist and finger exercises	No	Yes	Negotiation of daily activities between patient and therapist, focus on enjoyed activities	ND	Daily activities collaboratively agreed between therapist and patient, linked where possible with movements similar to exercises
		42		No				
Clementsen et al.[24]	2-3	14	AROM 4x/day	No	Yes	ADLs	Non-weight bearing until day 13, load-bearing as tolerated from day 14	No
Andrade-Silva et al. [23]	1	14	Wrist exercises provided	No	Yes	Light ADLs within pain limits	No impact activities or excessive effort in the first 14 days	No

Author	EM: mean no. of days surgery to mobilisation	DM: mean no. of days surgery to mobilisation	Exercise intervention	Removable splint provided when mobilised	Daily activities performed without splint	Activity types	Intensity	Therapeutic use[i]
Lozano-Calderón et al. [25]	8	49	Active and active-assisted wrist ROM exercises	Yes	Yes	Light ADLs	Lifting <2.5kg	Encouraged to perform light ADLs for the purpose of 'exercising' the wrist
Quadlbauer et al. [26]	1	35	Wrist and finger exercises	Yes	Yes	Light ADLs	Light	No
Valdes [22]	7	42	Wrist and finger exercises	Yes	Yes	Light ADLs Guided by pain	<1kg	No
Duprat et al. [27]	1	14	Wrist AROM	No	Yes	Light ADLs	Light	No
Iitsuka et al. [28]	1-3	42	Wrist AROM	No[ii]	Yes[ii]	ND	ND	No

[i] Activities and occupations selected as interventions to meet specific therapeutic goals (Amini et al., 2014)

[ii] Use of a wrist splint was not reported but assumed from the content of the paper. Performance of daily activities without a splint was therefore inferred.

ADL: activities of daily living; AROM: active range of motion; DM: delayed mobilisation; EM: early mobilisation; ND: not described

Outcomes

The results demonstrated that in groups where the performance of activities and ROM exercises were commenced prior to two weeks, there was generally greater wrist and forearm ROM and better function at up to eight weeks than when mobilisation was delayed until two weeks or later. Effect sizes are detailed in Table 6 and full outcomes in Supplementary File 2 (Appendix D).

Studies comparing <2 weeks with 2 to 3 weeks immobilisation

Five studies (Andrade-Silva et al., 2018; Clementsen et al., 2019; Duprat et al., 2018; Iitsuka et al., 2016; Watson, Haines, et al., 2018) compared mobilisation that commenced prior to two weeks with mobilisation that was delayed until 2 to 3 weeks. Of these, three were of good or excellent quality (Andrade-Silva et al., 2018; Clementsen et al., 2019; Watson, Haines, et al., 2018).

Range of movement

At the 6 to 8 week follow-up, greater wrist movement was observed with small effect sizes for forearm or wrist range of movement in three studies, in favour of early mobilisation (Andrade-Silva et al., 2018; Clementsen et al., 2019; Iitsuka et al., 2016), whereas no differences were observed in the study with the lowest risk of bias (Watson, Haines, et al., 2018). In two low quality studies small or medium effects were seen at 10-12 weeks for some ROM measures (Duprat et al., 2018; Iitsuka et al., 2016). At 26 weeks, small and medium effects in favour of the early mobilised groups were observed in one good (Andrade-Silva et al., 2018) and one excellent (Watson, Haines, et al., 2018) quality study, for some ROM outcomes. In neither of these studies did the authors report these as statistically significant differences.

Function

Self-reported functional scores for the DASH were better in two studies in the early mobilised groups (Clementsen et al., 2019; Iitsuka et al., 2016) with a small effect size at the 6 to 8 week follow-up. At 10-12 weeks one study (Iitsuka et al., 2016) reported a small effect size for the DASH and a medium effect at 26 weeks.

Pain

For pain outcomes, two studies (Andrade-Silva et al., 2018; Clementsen et al., 2019) showed lower pain with small effect sizes, in the early mobilised groups at 6 week follow-up and in one study this was maintained at 10 to 12 and 26 weeks (Andrade-Silva et al., 2018).

Studies comparing <2 weeks with 5 to 6 weeks immobilisation

Four studies compared mobilisation that commenced prior to 2 weeks with 5 to 6 weeks immobilisation (Lozano-Calderón et al., 2008; Quadlbauer et al., 2017; Valdes, 2009; Watson, Haines, et al., 2018). Larger effect sizes were seen in these studies than the previous comparison. Two of these were of good or excellent quality (Lozano-Calderón et al., 2008; Watson, Haines, et al., 2018).

Range of movement

In the studies that reported 6 to 8 week follow-up there was greater extension (Quadlbauer et al., 2017; Watson, Haines, et al., 2018), flexion (Quadlbauer et al., 2017; Watson, Haines, et al., 2018), and forearm rotation (Quadlbauer et al., 2017; Watson, Haines, et al., 2018) with predominantly medium to large effects. At 10 to 12 weeks small non-significant effects of early mobilisation were observed for supination in one study (Lozano-Calderón et al., 2008) and in another study (Quadlbauer et al., 2017), medium effects were seen for wrist ROM.

Valdes (2009) investigated the number of visits and days required to attain 40° wrist extension and flexion, demonstrating significantly fewer visits and days at large effect size, for patients who were mobilised prior to 2 versus 6 weeks.

Function

Better function was reported in two studies at 6 to 8 week outcomes (Quadlbauer et al., 2017; Watson, Haines, et al., 2018) with medium and large effects. In one fair quality study (Quadlbauer et al., 2017) a medium effect for function was observed at 10-12 weeks and this was maintained at 26 week follow-up.

Pain

Lower pain was reported in two studies at 6 to 8 week outcomes (Quadlbauer et al., 2017; Watson, Haines, et al., 2018) with small effects. In one of these studies

(Quadlbauer et al., 2017) lower pain was maintained at the 10 to 12 and 26 week follow-ups with small effects.

Adverse Events

Adverse events are reported in full in Supplementary File 2 (Appendix D). There were losses of fracture reduction reported in two studies at slightly higher rates in the early mobilised groups (Andrade-Silva et al., 2018; Watson, Haines, et al., 2018). In those studies, the differences were not statistically different. No other study reported losses of fracture reduction. Other complications were tendon rupture, carpal tunnel syndrome, tendinitis, complex regional pain syndrome (CRPS), and infection with no statistically significant differences between groups reported in any study.

Quality assessment

The scores from the quality assessment are shown in Table 8. The mean score was 20/28 (range 10-27). One study was graded as excellent (Watson, Haines, et al., 2018), three as good (Andrade-Silva et al., 2018; Clementsen et al., 2019; Lozano-Calderón et al., 2008), three as fair (Duprat et al., 2018; Quadlbauer et al., 2017; Valdes, 2009) and one as poor quality (Iitsuka et al., 2016). CEBM levels of evidence are shown in Table 6. Randomisation occurred in all but the three retrospective studies (Duprat et al., 2018; Iitsuka et al., 2016; Valdes, 2009). Participants were unable to be blinded to interventions in any study. Assessors blinded to group allocation were used in five studies (Andrade-Silva et al., 2018; Clementsen et al., 2019; Lozano-Calderón et al., 2008; Quadlbauer et al., 2017; Watson, Haines, et al., 2018). Calculations for sample size were conducted in four of the RCTs at a significance level of 0.05 and power of 80% based on detecting differences in pain (Andrade-Silva et al., 2018), function (Clementsen et al., 2019; Watson, Haines, et al., 2018), and wrist ROM (Lozano-Calderón et al., 2008). Of the eight studies, three failed to make adjustments for multiple analyses (Andrade-Silva et al., 2018; Iitsuka et al., 2016; Quadlbauer et al., 2017) and in three studies, confounding variables such as different surgeons or sites were not accounted for (Duprat et al., 2018; Iitsuka et al., 2016; Valdes, 2009).

Results from the TIDieR checklist can be found in Supplementary File 3 (Appendix E). The mean score was 8.5/24 (range 3-17), indicating an overall poor level of intervention reporting. Only one study provided details on educational materials given to participants (Valdes, 2009). In only two studies were comprehensive data given on procedures, interventions, who provided them, what modifications were made and how intervention adherence was assessed (Valdes, 2009; Watson, Haines, et al., 2018).

Table 8

Scoring of the studies according to the Downs and Black Quality Index

	Reporting										**External validity**			**Internal validity - bias**							**Internal validity - confounding**						**Power**	**Score/28**	**Grade**
Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
Watson, Haines, et al. (2018)	1	1	1	1	2	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	27	Excellent
Clementsen et al. (2019)	1	1	1	0	2	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	25	Excellent
Andrade-Silva et al. (2018)	1	1	1	0	2	1	0	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	23	Good
Lozano-Calderón et al. (2008)	1	1	1	0	2	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	1	1	23	Good
Quadlbauer et al. (2017)	1	1	1	0	2	1	0	1	0	1	0	0	1	0	1	1	1	0	0	1	1	1	1	1	1	0	0	18	Fair

	Reporting										External validity			Internal validity - bias							Internal validity - confounding						Power	Score/28	Grade
Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
Valdes (2009)	1	1	1	1	2	1	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	16	Fair
Duprat et al. (2018)	1	1	1	0	1	1	1	1	0	0	1	0	1	0	0	1	1	1	0	1	1	1	0	0	0	0	0	15	Fair
Iitsuka et al. (2016)	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	11	Poor

The final score, out of 28 points, was assigned one of four grades, in line with previous reviews, to give an overall rating: 'excellent' for 26–28 points, 'good' for 20–25 points, 'fair' for 15–19 points and 'poor' for ≤14 points

5.2.5 Discussion

The review focused on two objectives. First, to determine how early mobilisation regimes following distal radius fracture surgery were reported, with a particular focus on elucidating the inclusion of daily activities as part of early rehabilitation. Second, the efficacy and safety of early mobilisation regimes that commenced prior to two weeks was evaluated in comparison with mobilisation delayed until two weeks or later. The term early mobilisation is widely used in the literature, generally referring to the use of ROM exercises (Ikpeze et al., 2016). Exercise regimes are relatively well-understood whereas the influence of daily activity performance on recovery has lacked clarity and attention. While it was not possible to determine the degree to which early activity influenced return of function and movement, the review points to the important contribution of daily activities in rehabilitation. This small body of moderate quality evidence, in studies comparing mobilisation prior to and after two weeks of volar plate fixation of distal radius fractures, suggested that performance of daily activities in tandem with exercises prior to two weeks postoperatively is first, a common, but unstructured component of early mobilisation regimes, second, effective in achieving greater ROM, earlier return to function, and lower pain at up to eight weeks following surgery and, thirdly, generally safe as part of early rehabilitation regimes.

Recommendations on activity use are lacking in the literature and the safety of early fracture loading has been debated (Brehmer & Husband, 2014; Salibian et al., 2019; Smith et al., 2004). In general, the review confirms the safety of early activity. The parameters of early activity were not well-defined in the studies but commonly described as needing to be light, non-forceful, and within pain limits. Safety was shown by the lack of difference in adverse events between groups. While there were slightly higher rates of fracture position loss in two studies in early groups (Andrade-Silva et al., 2018; Watson, Haines, et al., 2018), these were not attributed to early mobilisation by the authors. It does however indicate a focus of further study. Any early mobilisation regime must be considered with respect to fracture severity, stability of fixation and associated soft tissue injury, and be individualised accordingly. The review nonetheless supports the safety of incorporating performance of daily activities into early rehabilitation.

The review shows that activity was recommended as part of early mobilisation regimes but highlights a lack of specification on the parameters of daily activities. With respect to splint use, the studies advocated the performance of activities without a splint in early groups, in some cases, immediately after surgery. There are two bodies of work that support this premise. The first is biomechanical and cadaveric research that demonstrated sufficient strength of volar locking plates in withstanding the forces of daily activities during early rehabilitation, in both extra- and intra-articular fractures (Alluri et al., 2015; Cooper et al., 2007; Dahl et al., 2012; Kim et al., 2017; Koh et al., 2006; Levin et al., 2008; Mansuripur et al., 2018; Osada et al., 2003). The second is observational and surgical studies where light daily activity was advocated early after surgery with a splint removed (Drobetz et al., 2016; Gong et al., 2015; Kwan et al., 2011; Osada et al., 2008; Waterbury et al., 2016). Collectively, these studies corroborate the findings of the review that early performance of daily activities, without a splint is suggestive of being safe, and is accepted clinical practice in many centres.

With respect to timeframes, early mobilisation was commenced prior to an average of day 4 postoperatively. This is a pertinent finding as therapists may be reticent to recommend activities in the initial weeks due to concerns about load to healing bone (Colaianni & Provident, 2010; Mehta et al., 2011; Smith et al., 2004). Commencing daily activities early after surgery may have particular benefit for some patients such as those at risk of greater joint stiffness, prolonged pain or a pattern of disuse (Mehta et al., 2011). Enabling early activity performance may build self-efficacy and confidence, factors which have been associated with better outcomes following surgery for distal radius fracture (Björk et al., 2020). Activities of increasing load, complexity and challenge can be gradually introduced, and as mastery of these activities is achieved confidence and self-belief is built (Hinojosa & Blount, 2014b). The findings of the review challenges hand therapists to consider earlier initiation of activity performance than may be traditionally practiced (Smith et al., 2004).

Recommendations regarding activity types and intensity were for the most part poorly described. Activity types were limited to self-care, those that avoided weight-bearing or lifting greater than 2 kgs. Some studies referred to non-impact activities but did not give examples. Observations from the first author's clinical practice suggest that patients often seek guidance as to what activities they are able to engage in. While it may be difficult to specify activities due to the complexity of movement during activity (Colaianni & Provident, 2010; Daud, Judd, et al., 2016b; Dy & Yancosek, 2017), more specific examples may be helpful. It would be beneficial in future research to examine the types of activities that could be recommended at various phases of bone healing.

Therapeutic use of activity, where activities or occupations are self-selected, meaningful and purposeful (Hinojosa & Blount, 2014b), was only described in one study (Watson, Haines, et al., 2018). In that study, valued and enjoyed activities were cooperatively selected, modified and performed as part of a home programme to promote movement and functional recovery (Watson, Haines, et al., 2018). The unique advantages of activity or occupation-based interventions may be underutilised in hand and wrist injury rehabilitation. Purposeful activities have been shown to enhance motor performance and observed to augment movement volume in healthy and musculoskeletal populations (Colaianni & Provident, 2010; Wilson et al., 2008). It is reasonable to consider that the greater ROM, function, and lower pain in the early groups were in part due to the performance of daily activities. The review draws attention to the potential for using purposeful activities and occupations in more intentional ways to enhance recovery from wrist fracture surgery.

The review investigated the effects of early performance of daily activities and exercise regimes on ROM, functional outcomes, and pain. The review suggested that there was greater ROM (Brehmer & Husband, 2014; Quadlbauer et al., 2017; Valdes, 2009; Watson, Haines, et al., 2018), earlier return to function (Brehmer & Husband, 2014; Quadlbauer et al., 2017; Watson, Haines, et al., 2018), and less pain (Watson, Haines, et al., 2018), at up to eight weeks, than in groups where activity performance and wrist exercises were delayed until two weeks or longer. The effects were greatest in the studies that compared early mobilisation with five to six, as opposed to two or three weeks, of immobilisation. This is unsurprising as it would be expected that longer immobilisation would result in greater joint stiffness. It highlights the importance of minimising the period of immobilisation wherever possible.

The benefits of better short-term outcomes should not be underestimated. Achieving earlier return of movement and function is likely to have wide-reaching implications for individuals and society. Benefits may include improved mood, well-being, quality of life, higher rates of patient satisfaction, reduced loss of earnings, less need for support services, fewer hand therapy appointments, and less time away from recreational pursuits (Brehmer & Husband, 2014; Drobetz et al., 2016; Guzelkucuk et al., 2007; Ikpeze et al., 2016; Mehta et al., 2011; Valdes, 2009). These early outcomes are purported to be highly advantageous to people with injury but are not always given attention in outcomes research.

The moderate quality of the evidence must be considered when interpreting the findings of the review. Quality issues were statistical analyses that did not take multiple comparisons into account, lack of blinded assessors and non-reporting of losses to follow-up. The predominant methodological flaw of the review was that, with the exception of one study (Watson, Haines, et al., 2018), fidelity of interventions was poorly addressed. Intervention fidelity refers to the degree to which interventions are reported and implemented in the manner intended (Hildebrand et al., 2012; Murphy & Gutman, 2012). Using the TIDieR scale, failings across all aspects of reporting and monitoring were noted. On the whole, interventions were inadequately or only partially described with respect to providers, locations, methods of delivery and personalisation of the programmes. Adherence was monitored in only one study (Watson, Haines, et al., 2018). The lack of fidelity in the postoperative interventions makes it difficult to determine whether the effects seen were due to the interventions themselves or other factors not acknowledged by the authors.

Limitations of the review include the small number of studies of varying purpose, design, and quality. Low level observational studies were included, due to their relevance to the review question but influence the strength of the findings. Only one author conducted the search which could have resulted in missed studies and potential bias in selection of studies. Only one author assigned the level of evidence and scored the TIDieR which may have resulted in under or over-representing the quality of the studies. Standard deviations in one study had to be estimated in order to calculate effect sizes (Lozano-Calderón et al., 2008). Directions for future research are suggested including biomechanical evaluation of movement during daily activities after wrist surgery and investigating the independent effect of activities differentially from exercise approaches. Qualitative enquiry may illuminate patient perspectives on how activities influence recovery from wrist fracture.

5.2.6 Conclusions

The review found evidence that performance of light, non-forceful daily activities, without a splint in situ, was commonly recommended in the first two weeks following volar plating of distal radius fractures as part of early mobilisation regimes. Findings suggest that a range of light activities can be safely initiated within two weeks of surgery and incrementally increased during the first six weeks. The parameters of early daily activities were poorly specified in most studies and is an area that should be addressed in future research. Greater ROM, earlier return to function and lower pain might be expected at six to eight weeks after distal radius fracture fixation if mobilisation is commenced within two weeks of surgery, compared with prolonged wrist immobilisation. There are important psychological and social benefits to achieving earlier return to function and these factors should have greater focus in future research. The early mobilisation regimes in the review included performance of daily activities without a splint alongside exercise routines and points to the role of both approaches in promoting recovery of movement and function following volar plating of distal radius fractures. It challenges hand therapists to incorporate activity into early postoperative rehabilitation, and to conduct further research into the mechanisms and effects of activity and occupation-based interventions.

5.3 Chapter summary

Chapter 5 presented a systematic review published in the peer-reviewed journal, Hand Therapy. The review is the first known to have explored how activity is recommended in early mobilisation protocols or taken a ‘deep-dive’ into what constitutes early mobilisation. The review sheds light on the potential of occupation as a rehabilitative strategy in early postoperative fracture management but highlighted the lack of specification in the prescription of therapeutic occupation.

First, it was not possible to define the types of activities that may be considered appropriate for various stages of bone healing, or even if such prescriptive guidelines are needed. Describing activities as ‘light’ was a non-specific, poorly defined term that requires greater explication. What constitutes acceptable loads to the fracture was also poorly defined. Second, the review did not explore the ways that patient’s themselves may perceive the therapeutic value of activities and occupation. To gain a comprehensive picture of the value of occupation in remediating wrist stiffness and function after surgery a patient perspective is needed. Last, the review showed that performing daily activities may play a greater role in the restoration of wrist movement than currently known. The need for further research that investigates occupation and exercise-based approaches independently was reinforced. The following two chapters present a qualitative study that was conducted to understand the perspective of patients immersed in the rehabilitation journey.

Chapter 6 Published study III: Concepts and study procedures

6.1 Overview

Study I showed that movement produced by purposeful activity differs with respect to quality and quantity from exercise routines or non-purposeful movement. Study II elucidated that occupation plays a role in the recovery of movement after surgery. These systematic reviews set the stage for further research into the specific mechanisms of how occupation might work to bring about change after surgical treatment of a distal radius fracture. The thesis now shifts to the generation of new knowledge via primary research.

Chapter 6 and Chapter 7 present a qualitative study that addresses RQ3: What are the experiences and perceptions of patients on how participation in daily activities and occupations influence recovery after surgery for distal radius fracture?

The study explored perspectives on how daily activities and occupation influenced the rehabilitative journey. The purpose of this chapter is to present an overview of the study, discuss the underpinning concepts, and give a more detailed account of the analytic process than is possible in a publication. The published article is then presented in Chapter 7 .

6.2 Purpose of the study

Study III used the qualitative methodology of Interpretive Description (ID) and was designed as a prequel to study IV which used the quantitative approach of objective measurement and statistical analysis. In study III, I wanted to find out how daily activity and occupation was perceived during the early weeks of recovery, the types of purposeful activities people elected to perform, and how they decided what they could do. Once I had a clearer picture of how occupation might be used, I could then undertake objective analysis of movement.

6.3 Philosophy and methodology: Critical realism and Interpretive Description

Interpretive Description methodology was used in study III (Thorne, 2016c), underpinned by a critical realist perspective. Critical realism research aims to investigate complex phenomena and discover hidden mechanisms. ID is a methodology attentive to health practice questions (Hunt, 2009). Initially developed within the discipline of nursing, ID has been adopted by allied health professions including occupational therapy and physiotherapy. ID arose from the need to have a methodology focused on solving real-world clinical problems. Inspired by grounded theory, phenomenology and ethnography, ID takes a divergent view in that it steers away from theory generation towards practice-based concerns (Barolia et al., 2013; Olufemi-Yusuf et al., 2018). Thorne claimed that health researchers frequently failed to adhere to the conventions of such methodologies, due to lack of a more suited approach. This led to incongruencies between methodology and method, and a lack of study rigour or so-called “sloppy science” (Thorne et al., 1997, p. 172). ID focuses on identifying commonalities and differences and frames studies in ways that will contribute to knowledge about clinical practice (Thorne, 2018).

Elemental to an ID study is an understanding of the existing knowledge surrounding the research question (Thorne, 2016c). Rather than putting established disciplinary knowledge and evidence to one side during analysis, as might occur in a grounded theory analysis for example, ID uses existing knowledge as a platform from which to grow new knowledge. Study III explicitly builds on theoretical perspectives about how activities influence recovery from upper extremity injury. Concepts such as pain mitigation, engagement with rehabilitation, or utilisation of established motor patterns have been written about in the hand therapy literature, but frequently lack supporting evidence. The intention of study III is to explore whether such concepts hold true for people with a surgically repaired distal radius fracture, and to bring new concepts to light. Preconceptions are discussed below in 6.3.1.

Critical realism intersects well with ID at this juncture, as both approaches promote a deep knowledge of the existing theory that have informed the research question and recognise that knowledge cannot be fully put aside during data analysis. Critical realism research is theory-driven, the existence of theories is accepted but through a critical lens (Fletcher, 2017; Williams et al., 2017). Research is constructed to test theories that offer plausible, but possibly fallible, explanations (Ackroyd & Karlsson, 2014; Cruickshank, 2012). This research is not focused on theory-generation but rather on theory-exploration. I wanted to find out not only *if* activities and occupations influence injury recovery, but *how* they do so. Do the existing theories hold true from a participant's perspective and what are the factors that affect an individual's willingness or ability to engage in activities and occupations?

ID is aligned with an interpretive approach to inquiry whereby researcher and participants work together to create a narrative about a phenomenon (Barolia et al., 2013; Hunt, 2009; Teodoro et al., 2018). Knowledge is attained through exploring the experiences and perceptions of individuals and the contexts in which events occur (Hunt, 2009). Study III therefore primarily used interviews where researcher and participant worked together to construct new knowledge about the place of occupation in rehabilitation from surgical treatment of a distal radius fracture. The study was conducted in the 'real-world' environment of the participants home in keeping with the precepts of critical realism that advocates for open-environments.

6.3.1 Key preconceptions

A number of concepts as to how occupation and purposeful activities influence recovery following upper extremity injury have been proposed. Such concepts are important to make explicit as they informed the interview question guide in study III. One concept is that movement embedded in activities involves familiar motor processes and can therefore be performed automatically and with greater ease than a new movement pattern (Colaianni & Provident, 2010; Weinstock-Zlotnick & Mehta, 2018). Wrist ROM exercises for some individuals are challenging to perform and the familiarity of daily activities and occupations may promote more natural movement, initiated with greater ease. Another commonly purported concept is the effect of enjoyed activities on ameliorating pain. Participating in an activity that requires focus can divert attention away from uncomfortable movement and onto the activity itself (Dewan et al., 2013; Mehta et al., 2011; Nelson et al., 2002; Omar et al., 2012). While this premise is widely held, it is unknown whether this is true for people in the early weeks following a surgical procedure of the wrist.

It is often claimed that occupation-based therapy enhances engagement in the rehabilitative process, due to activities being purposeful and holding meaning to the individual (Chan & Spencer, 2004; Colaianni & Provident, 2010; Lequerica et al., 2009). This effect was observed in one study where individuals with hand injury were seen to be more motivated to perform therapeutic activities than exercises (Guzelkucuk et al., 2007). The promotion of self-efficacy has been advanced by some authors for how activities and occupations promote injury recovery (Mehta et al., 2011; Perez-Marmol et al., 2017). Poor self-efficacy has been shown to predict higher levels of disability (Pérez-Mármol et al., 2016). It has been suggested that engaging in motivating, enjoyable activities builds confidence and provides some reassurance that disability will not last (Guitard et al., 2018; Mehta et al., 2011; Pérez-Mármol et al., 2016).

Concepts from studies I and II also informed this study. Study I showed that movement was enhanced during purposeful activities, suggesting that if people perform valued activities during rehabilitation, they may produce more movement volume than by only performing exercise repetitions. Study II introduced the concept that people who perform activities alongside exercise repetitions during early mobilisation, regain movement and function faster than people who are immobilised for longer periods of time. I designed questions in study III that explicitly explored perceptions and experiences about wrist movement during early rehabilitation.

6.3.2 Pre-suppositions interview – lifting up the sacred rocks

Thorne (2016d) acknowledges that researchers add breadth to inquiries by bringing their own knowledge, experiences, and assumptions to the research. This embedded knowledge is integral to the research process, but must also be challenged and exposed, to ensure a rigorous and transparent investigation. I recognised that an inherent power imbalance could occur between myself and my participants due to my relatively greater clinical knowledge. This knowledge could also prevent me from being open to new perspectives put forth by participants. To expose my theoretical allegiances and personal ideas, a presuppositions interview was conducted prior to the first participant interview, by two of my supervisors, Valerie Wright-St Clair, and Nada Signal. The interview explored what brought me to the topic of my thesis and the trajectory of my career. During the interview I was asked how I would remain reflexive and open to unexpected findings. My supervisors encouraged me to set aside my clinical assumptions and be attentive to the language of my participants that may reveal emotions, difficult to articulate concepts, or experiences at odds with what I may expect. Excerpts from that interview are included here to illustrate some of the challenges and reflective strategies suggested. The text has been condensed and paraphrased for readability.

> Supervisor: So, Julie, talk to us about what brings you to this topic. The questions that you're asking.
>
> Julie: … I remember last year, I had a student, and I was with a patient who was struggling with pain. And I took this [activity] approach with my patient. Afterwards the student said, that was really interesting, really cool, how you did that. And she observed some different things. She said, well, you know, the lady seemed to be able to move a bit more than when we tried doing the exercises with her. Yeah, so I guess that's always where my curiosity has been. And I've always had some kind of everyday objects in my drawer that I can pull out. … But I've always felt that there's not a lot of evidence to back up that approach. And I've always struggled with how to use occupation in an optimal way. By doing this as a research project I wanted to be able to formalise or structure some ways about how to use activities and occupations in my practice.
>
> Supervisor: So how in this whole process, will you stay open to the things that you don't know, the things that might surprise you?
>
> Julie: I guess one thing is that I need to be a good listener. Because my natural inclination is to jump in and solve people's problems, as clinicians like to do, we like to give advice, we're very good at talking to patients… So, to listen, I guess, would be one thing. … It's been interesting, as I've written questions for the interview protocol, how I've changed, I've percolated thoughts along the way and changed how I originally might have written my

questions, I've thought how I could reframe questions to be more open. Try not to have too many preconceived ideas about what I want to find.

Julie: I also think that being part of a different research team [neurorehabilitation] has been good for me. It's a completely different clinical focus, but it has challenged me and made me think outside the square. You know, Sally Thorne would say, looking for some commonalities, but looking for some differences as well. Early on Nada challenged me to look at the motor control literature and, and I felt resistant to start with. Like, I don't really want to do this, but I also know that it's good to explore other ideas and other theories, other ways of thinking. Being part of this research team has helped me find my voice in this [occupation] space, because I've had to defend my ideas, and think about how other theories can also inform what we do in musculoskeletal practice.

Supervisor: And that's those moments of feeling uncomfortable, that you go, Well, hang on. Why is that? And asking what am I not seeing? What am I not asking about? And perhaps ask your participants towards the end of the interview. What have we not talked about yet? And to really listen you need to be prepared to be vulnerable. Because it might be uncomfortable but go with that sense of discomfort… And reflecting on how you're coming to this with your previous knowledge, or existing knowledge and experiences. How do you work with it and can you put them aside?

Julie: I've been thinking a bit about that. It's interesting, because with critical realism, theories are important, theories shape our realities, and what we know about the world. And so those theories are important, but they may be fallible as well. So those theories should be critiqued and scrutinised.

Supervisor: When you were talking about that, it made me think about that kind of confirmation bias that we have, you know, we, look for data points, which confirm our beliefs and empathy, all those concepts that underpin them. How, do we look for things which counter our beliefs.

Supervisor: I think it's the thinking about the things that surprise you, the things that don't line up with what you thought and always trying to find that space… This is what will hold you, the curiosity and the wonder and the things you didn't know would be there.

Julie: That's a good thing to keep in mind when I'm interviewing, to allow space to ask those questions that might go off in a

> different tangent or things might sit in contradiction to what I think should be the right answers. One of my colleagues said oh its great Julie, it might change the way we do things.
>
> Supervisor: Lift up a few sacred rocks and peer underneath them. See what lives there.

The interview was helpful in delineating me as a researcher rather than a clinician. It helped me to differentiate the two competing roles and to enter the study as a researcher. Throughout the study I kept coming back to the interview transcript to remind myself to remain reflexive and open to challenging existing knowledge and practice paradigms.

6.4 Procedures used in the study

The following section describes procedures used in study IV that are not covered in depth in the published article. The procedures are those required for ethics, the development of the activity and exercise log, the iterative development of the interview guide, procedure variations due to COVID-19, and the decisions made regarding the study sample.

6.4.1 Ethics

Ethical approval for study III was provided by the Auckland University of Technology Ethics Committee (AUTEC), study number 19/224, on the 31st July 2019. The approval letter is shown in Appendix F and CMDHB localities approval in Appendix G. As the study was to be conducted in the homes of participants it was important to show that I had considered safety aspects of field-based research. A researcher safety protocol was submitted and is included in Appendix H. The study participant information sheet and consent form are in Appendix I and Appendix J.

6.4.2 Data generation

Data were generated via an activity and exercise log and a semi-structured interview.

Activity and exercise log

Between weeks three and six postoperatively participants were asked to complete an online activity and exercise log via the application Microsoft Forms. A printed copy was available if needed. The log contained 12 multichoice questions about exercises performed that day, the types of activities performed, pain and stiffness, the difficulty of performing activities, and one question about kinesiophobia. The log is included in Appendix K. The rationale for the log was that I thought participants may find it difficult to recall what activities and exercises they did during the first six weeks. Participation in activity is by nature tacit and hidden. The log was designed to elucidate data without pre-empting or influencing behaviour during that time. It was acknowledged however, that keeping a diary, may have influenced participant behaviour. For example, patients may have felt anxious about not doing enough exercises, may have reported inaccurately, or done more activities or exercises than they otherwise would have. To mitigate this, it was made explicit that the log was not intended to be a ‘test’, that the focus was the experiences of participants not whether or not activities or exercises were performed.

The log was developed from the Activities of Daily Living taxonomy of Törnquist and Sonn (1994), occupational performance problems identified by hand therapy patients (Poulsen & Hansen, 2018), the Meaningful Activity and Participation Assessment of Eakman et al. (2010) and identification of valued activities of New Zealand Māori and Non- Māori (Wright-St Clair et al., 2017; Wright-St Clair et al., 2012). The log was reviewed by two Māori patients in hand therapy at the Manukau Super Clinic to check for accuracy of Te Reo (Māori language) and usability.

Semi-structured interviews

The interview guide was informed by both critical realism and ID. The concept of causation is foundational within critical realism. Critical realists hold that causation is contingent or dependent on the context in which the mechanism functions, that social action is always constrained and facilitated by external structures (Maxwell & Mittapalli, 2010; Smith & Elger, 2014). As with ID, critical realist interviews do not aim to set aside existing theory but rather to test implicit knowledge in a theory-informed manner (Manzano, 2016; Thorne, 2016c). The interviews were a semi-structured exploratory style (Manzano, 2016). They not only investigated the perceived causal link between meaningful activities and injury recovery but also the 'how', 'why' and 'when'. The questions were designed to explore the existing theories on activity participation (those outlined in 6.3.1), and to elucidate the contextual factors within which the mechanism of activities/occupations may operate (Maxwell & Mittapalli, 2010; Smith & Elger, 2014). ID interview questions, according to Thorne, are often curiosity based, questions that clinicians would ask if they had more time. Thorne tempers this nonetheless by reminding clinical researchers to set aside clinical-type questions and take on a research-interview mode (Thorne, 2016c). Questions should be designed to elicit hidden information and not simply confirm the researcher's own hunches. Thorne also cautions researchers not to have overly inflated expectations about what participants will be able to articulate, that researchers should be realistic and must allow sufficient time to allow a participant's story to fully unfold (Thorne, 2016c). For this reason, participants were consented for a 60 to 90-minute interview.

An interview guide was developed with questions built around four broad areas: advice around activity given by health professionals; parameters of activities participated in (types, range, modifications, decision making process); experiences of doing activities (ease of movement, perceived threat, enjoyment, fear, pain, anxiety); perceptions on activities as therapy (motivational value, utility, perceived meaning of activities, influence on self-efficacy). The questions were open-ended and formed a framework only. The guide was trialed in the initial few interviews and further iterations were developed as the interviews progressed. An initial and later iteration of the interview guide are presented in Appendix L and Appendix M.

6.4.3 Procedure variations due to COVID-19

During the data collection phase of the study the COVID-19 global pandemic began affecting New Zealand. Between March and June 2020 lockdowns were implemented by the New Zealand Government to mitigate the spread of the virus. During this time there were varying restrictions on personal and community activities and government health orders prevented face-to-face research activities.

Responses to COVID-19 had several implications for this study. In the latter half of February 2020, it was necessary to screen all study participants about previous overseas travel and any contact with known COVID-19 patients prior to conducting interviews. During the lockdown phase an ethics amendment was sought to allow data collection via remote methods such as zoom or telephone. The approval letter dated 23 April 2020 is in Appendix N. Six of the twenty-one interviews were conducted via an online video platform or by phone call. Although face-to-face interviews were my preferred method of data collection, I felt I was able to conduct those interviews in a way that fostered connection and engendered rich conversation.

6.4.4 Study sample

In Chapter 7 I detail the study setting, inclusion criteria, and recruitment procedures. In the following section I detail the rationale for the use of purposive sampling as that is not included in the published article.

The number of participants was based on criterion purposive sampling (Sandelowski, 2000) to ensure adequate maximum variation of the following criteria: age; gender; ethnicity; degree of pain, kinesiophobia (fear of movement); wrist and finger stiffness. Critical realists argue that diversity is fundamental to humanity and in research should not be controlled for but rather intentionally sought out (Maxwell & Mittapalli, 2010). Similarly, ID favours a sampling strategy that will achieve a variety of perspectives and add depth to understanding the research question (Thorne, 2016c). The criteria were selected to ensure inclusion of a range of characteristics representative of those seen in clinical practice. During recruitment I entered participant characteristics according to the defined criteria on a spreadsheet. With every new potential participant, I conducted a phone screen to ensure they met the inclusion criteria and to check against my purposive sampling criteria. If I already had sufficient representation of certain criteria, I politely declined their participation. During recruitment, I only needed to decline a small number of people as sufficient natural variation occurred with potential participants.

Ethnicity

This study purposively sampled for diverse ethnicities. The research included a focus on recruiting and retaining Māori participants. Māori, the indigenous population of Aotearoa, make up 16% of the overall population and have poorer outcomes across a raft of health indicators (Anderson et al., 2006; Robson et al., 2015). Collaboration with Māori in research is seen as an important strategy for illuminating mātauranga Māori (traditional knowledge) and working towards equitable outcomes (Hudson & Russell, 2009; Ministry of Health, 2014; Ministry of Research Science and Technology, 2005). Research strategies were developed in consultation with the Auckland University of Technology Mātauranga Māori Committee and included intentional targeting of Māori during recruitment, use of Te Reo Māori (Māori language), including hikuaua (art patterns) in participant documents, allowing extra time during interviews to facilitate whanaungatanga (connection), and inclusion of whānau (family) during interviews.

Clinical presentation: pain and kinesiophobia

Pain severity was measured via the pain subscale of the Patient Rated Wrist and Hand Evaluation (PRWHE), a validated and reliable measure of patient-rated pain and disability in the upper extremity (MacDermid, 1996; MacDermid et al., 2000; MacDermid et al., 1998) (Appendix O). Kinesiophobia is the fear of movement and was measured by the Tampa Scale of Kinesiophobia-11 (TSK-11) (Woby et al., 2005) (Appendix P). I wanted to ensure the study included people with both high and low levels of pain and kinesiophobia.

Clinical presentation: wrist and finger stiffness

Wrist stiffness was scored as: >50%, 20–50%, or <20% of the contralateral side based on the criteria of Javed et al. (2015). Finger stiffness was considered to be present if there was greater than 1cm distance between the fingertip and the distal palmar crease for any one finger (Egol et al., 2014). It was important that my sample included people who had more severe joint stiffness so that I was interviewing people whose recovery was likely to be more challenging.

6.5 The work of data analysis

Chapter 7 presents the results of the analysis but does not detail the analytic process. This subsection discusses the analytic journey and strategies used. Analysis of qualitative data is by nature immersive and iterative and is not reported in detail in the manuscript. Several strategies were used to ensure a rigorous and deep analysis that warrant explanation. Excerpts and explanatory notes of my reflexive journal are provided here to illustrate how I approached data analysis and developed the final themes.

6.5.1 Reflective journal

One of the key strategies I used throughout the study was a reflexive journal. Following each interview, I wrote field notes to record immediate reactions, insights, critical reflections, potential refinements to the interview guide and emerging patterns. This process kept me alert to less obvious narratives, a strategy described by Sally Thorne (2016e) as 'envisioning possibilities'. During the interview phase I was constantly thinking, allowing my mind to percolate on the interview data and how it might ultimately come together as different strands.

I have included here three excerpts from an early, middle, and late interview. These excerpts illustrate how my thinking deepened as the interviews progressed. Pseudonyms used in study III are used here to replace participant names.

Excerpt one: *2nd December 2019*

This excerpt illustrates that during the initial interviews I was struggling to maintain researcher curiosity and distance. The excerpt also demonstrates my nascent curiosity and how the interview prompted me to go back to the literature.

> I felt that I did better at allowing time to listen and let my participant express her own ideas. I found it hard to establish a balance between allowing her to come up with her own thoughts while providing some structure and context. An example was when I wanted to explore the idea of automaticity/familiarity of movement – the idea of getting lost in activity and moving wrist without knowing about it. I presented the idea but then felt I pre-empted her thinking. Still difficult for me to think about what I

> don't know, what else I could be exploring that I'm not expecting to find – not quite sure how to do this. I felt like I got some very rich data. Just need to be careful not to keep confirming what I think I already know. I'm still concerned that I'm missing the hidden dimension – the things I don't know – how do I access that without having an idea about what I'm trying to provoke – discover?
>
> A couple of new ideas that came out … were the length of time it took to do the exercises and the (unprompted) idea that they got a bit boring, so it was good to mix things up by doing some activities. I've been reading about psychological flow. It might be interesting to explore the concept of how participants arrive at the right level of challenge. How do they decide what the correct level is? Pain, time? Intuition? How does this compare with the challenge provided by exercises? Can this feed into intervention development?
>
> Learning points for next interview: Think about how to ask about 'the just right challenge' – maybe introduce the idea and ask for responses.

Excerpt two: *24th February 2020*

As the interviews progressed, my journal entries were more critical and probing in nature. I attempted to remain curious and allow my thinking to be immersed in creative discovery (Thorne, 2016a). In time, these notes began to take shape, forming clusters of concepts that compared and contrasted reflections from earlier interviews. This early analysis is described by Thorne (2016e) as a 'testing of relationships', a process of going back to the concepts that framed the study and challenging the assumptions I brought with me. Excerpt two illustrates my developing skills as an interviewer.

> In supervision recently, my supervisors listened to some short extracts from an interview. They feel I am still using too much clinician language. They felt the questions I was asking were the sorts of things I would ask about or observe in clinical practice. Also, that I'm leaping ahead too much, always thinking about what's in front and what's on my list of things to ask, not getting to the depth of the story. I was challenged to be a 'naïve enquirer', to listen for cues that indicate emotional responses. Listen for feelings. Use the words of the participant to find out what's sitting behind the narrative.

> The interview with Bill today went better... I was able to draw out his thoughts by listening more carefully to the language he used and listen for cues that might express emotions. I took more care to listen carefully and to mentally (and physically) jot down phrases or words that I could pick up on and reflect back to him in an open ended question. An example of this was he made a passing comment that using his hand to the capacity that he could 'settled' him. I came back to this when there was a pause in the dialogue and asked what he meant by this. This opened up some expression of ideas on how his upbringing had formed him into a 'tough' resilient person who could deal with injury and who was not going to let an injury or disability define who he is. Fascinating.
>
> An idea that came through strongly from the interview is the arena of mind-body connection ...It felt like I was starting to explore the unknown, the unexpected and the surprising. The strength and deliberateness with which my participants harnessed the power of their psyche for recovery was an emerging and novel concept. For Bill a strong sense of pride in his resilience fuelled his actions towards recovery (doing everything he possibly could, not being fearful of using his hand, not allowing other people to 'tell' him what was ok.
>
> Today during the interview with Sue, I listened for language that would indicate feelings or 'ways in' to explore the depth to her experiences. I tried reflecting Sue's language back to her and going back to earlier themes that had come up. I picked up on words/phrases such as "frustrating", "it was scary", "the pain was always there", "I don't like it when..." "it's been harder than I expected". Sometimes it felt like I was probing, and I sensed she was feeling a little uncomfortable, so I took the time to explain why I was asking the questions and that seemed to help, it gave her some more context as to what I was exploring, and she was happier to expand on ideas. I tried not to 'leap ahead' or worry about my list of questions, rather to go with the flow of the interview.

Excerpt three: *27th March 2020*

After each interview I would listen to the audios. I would pause, think, take notes, and speak aloud to process and differentiate ideas. The excerpt from this latter phase journal entry illustrates how I felt as I approached coding and my ongoing examining of relationships between participant narratives, existing theories, and clinical implications.

> COVID-19 has hit. How the world has turned upside down in just the space of a few weeks. It's frightening and isolating and uncertain. I wonder where we will be when I look back on this later on. I'm grateful to be able to continue my research at the moment. I'm gearing up to be brave enough to start coding. I am super nervous about getting up close and personal with the data, and whether I'll be able to make a coherent whole. There are so many complexities and layers to what my participants have shared that I'm worried about being able to do justice to their stories.
>
> I had a lovely interview today. I feel like I've got better at listening to the language of my participants, reflecting back, and digging deeper. Marie expressed an interesting perspective about using her hand for the first time, how it did not feel normal … that she had to make a deliberate choice to use her right hand. This contrasts with Karen – she did not force herself to use her wrist so much – she'd only use it if she felt it was safe or she could do the activity. – these two data sets would be good to look at and contrast the language used…Perhaps as therapists we use unhelpful language. We say things like don't' do this and don't do that but may not use language that facilitates reengagement with activity.
>
> This is interesting to evaluate when thinking about people with movement aversion. Perhaps it is those first early experiences of the wrist feeling so uncomfortable and wrong (awkward was how June described this) that sets up a pattern of neglect. And it is the people who manage to break through that first barrier that sets them on a path of reengagement with usual activities. It reinforces the idea that activities and exercises act differently.

6.5.2 Thematic analysis

Data analysis followed the steps of reflexive thematic analysis (Terry et al., 2017) and is detailed in the manuscript in the following chapter. This section illustrates the process of how I conducted coding and theming.

Strategies of coding

Coding of the transcripts took time. I deliberately slowed my pace to allow time to read, re-read and reflect. I wrote tentative codes, some remained until the end of coding, while others were relabelled or deleted as coding progressed. Initially, I struggled to find language that was true to the narrative while being analytic in nature. I took time with a chunk of data, trying to understand the nuances, remembering that participants were also often struggling to find language. As time went on my labels changed. Some of my early codes were too broad and as coding progressed there were a greater number of latent codes and those using gerunds. An example of this is an initial code labelled 'feeling the loss of function', I later renamed this to 'feeling upset or frustrated by the loss of function' to encapsulate the emotive component more accurately. Another example was data around the notion of occupational balance. Initially I had coded data where participants talked about the routines of everyday providing motivation to get better as 'occupation motivates me to get better'. As I read further, I realised there was a deeper idea being expressed. That participants were talking about the experience of occupational loss and the disorienting effect that had on their wellbeing. I subsequently recoded this data as 'the doing of everyday and psychological wellbeing, occupational balance'.

As my coding progressed, I noticed that coding of one transcript would prompt me to think about a previous transcript where I may have missed the nuance of some data and had not coded it similarly. I would go back to early transcripts and add a code and in doing so continued to go deeper with coding, a process known as recursive coding (Terry et al., 2017). An example of this is an early interview with Natalya. Natalya related an incident when she had dropped a plate unexpectedly. I had initially coded this as 'activity has an unpredictability to it', to denote that performing activities sometimes demanded unexpected movement that resulted in pain or dropping something. In a later interview, June spoke about feeding her ducks and her wariness about taking the food bucket near the ducks for fear that they would get into it and June would not be able to control them. So, June would avoid or adapt the activity in order to avoid sudden potentially painful or harmful movements. While transcribing June's interview and reflecting on her story I recalled that Natalya had taken the same approach, so I went back to Natalya's transcript and added the code 'adapting an activity in order to avoid sudden painful movement'.

Once coding was nearing completion, I went through all my coding to check for duplicates and check codes that seemed ambiguous or those that didn't say anything about the data.

Strategies of theming

Once the coding was completed step three began: constructing themes. One method I used was to print out the codes. I laid them out on a desk and moved them back and forth to try out different groupings based on how the codes might logically be delineated. I placed my question in the centre to keep the research focus fore of mind. Figure 8 shows an iteration of the prototype themes and Figure 9 shows detail of two coding subsections in close-up. Another tool I used was an online mind mapping tool from mindmeister.com. An example of this mind map is shown in Figure 10. A further strategy was to take a photo of the coding on my desk and use photoshop to draw circles and arrows to depict relationships. Candidate themes were revised and finalised through discussion at supervision sessions.

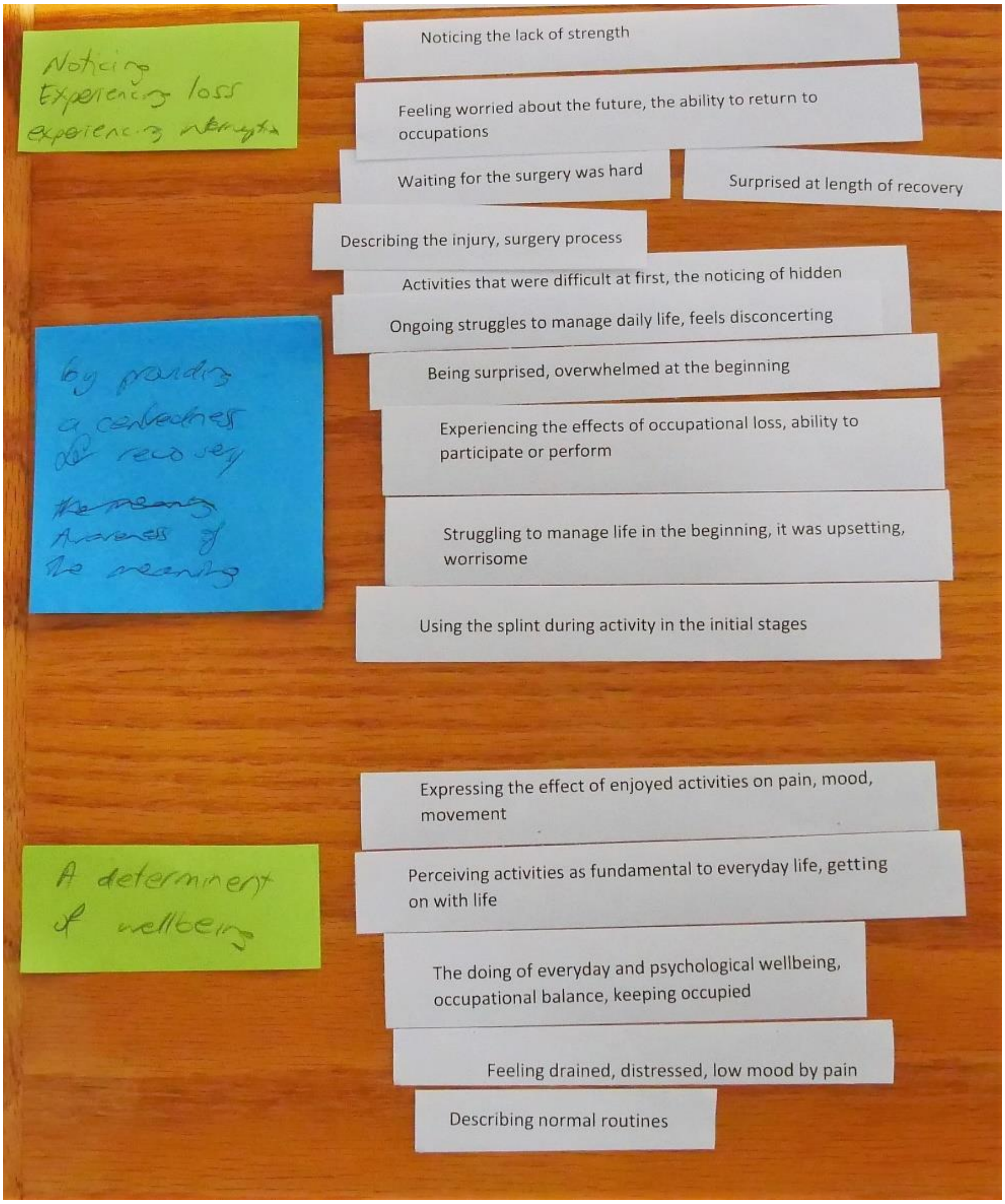
Figure 8

Illustration of the process of developing themes

Note. White tags are codes, blue are prototype themes and green potential sub-themes

Figure 9

Illustration of an iteration of theming



Note. White tags are codes, blue are prototype themes and green potential sub-themes

Figure 10

Illustration of a mind map section used during the development of themes

6.6 Conclusions

Chapter six presented the purpose of study III, a discussion on the methodology of Interpretive Description and the ways in which critical realism underpinned the study. Study procedures that demonstrated the rigour of study III were presented in more detail than the ensuing published article allowed. Rigour was demonstrated through a pre-suppositions interview that challenged my preconceptions and prepared me for undertaking the interviews and analysis. Explanations are given on decisions made regarding sampling procedures and data generation. The process of data analysis is discussed in detailed with illustrations of methods I used to support my thematic analysis such as reflective journaling, mind-mapping, manual sorting, and categorization of the codes.

The following chapter presents study III in the form of a published article.

Chapter 7 Published study III: "The more I do, the more I can do". Perspectives on how performing daily activities and occupations influences recovery after surgical repair of a distal radius fracture

7.1 Chapter overview

This chapter presents the published article of a qualitative study (study III).

The manuscript was published in Disability and Rehabilitation (Collis et al., 2021). The full citation for the article is:

Collis, J. M., Mayland, E. C., Wright-St Clair, V., & Signal, N. (2021). "The more I do, the more I can do": perspectives on how performing daily activities and occupations influences recovery after surgical repair of a distal radius fracture. *Disability and Rehabilitation*, 1-10. https://doi.org/10.1080/09638288.2021.1936219

The manuscript is included here with citations, figures and tables formatted consistent with the thesis. A copy of the published article is found in Appendix Q.

7.2 Published article

7.2.1 Abstract

Purpose

The study aimed to explore perceptions and experiences about how engaging in daily activities and occupations influenced recovery in the first eight weeks after surgical treatment of a distal radius fracture.

Methods

Twenty-one adults completed an online activity and exercise log then participated in a semi-structured interview between weeks 6 and 8 postoperatively. Interviews were transcribed and analysed using reflexive thematic analysis.

Results

Daily activities and occupations were highly influential in facilitating recovery of movement and function of the operated limb. Five themes provided an understanding of how occupation operated to promote recovery. Occupation was

(i) a primary driver of the rehabilitative process, providing an impetus for recovery, (ii) offered ready-to-hand challenges for opportunistic, automatic movement, (iii) invited intentional use of the affected wrist, (iv) habituated the wrist to movement through repetition and confidence-building and, (iv) drew on psychosocial resources to enable reengagement with life activities and roles.

Conclusions

Incorporating the performance of graded, modified activities during the early weeks of rehabilitation creates opportunities for wrist movement, enhances wellbeing, and assists in the habituation of wrist movement. Activities and occupations can be used as a therapeutic strategy to promote recovery from surgical treatment of a distal radius fracture.

Implications for rehabilitation

- Rehabilitation after surgical repair of distal radius fractures has traditionally focused on exercise routines
- Daily activities and occupations can also be used to promote wrist movement and function during the early weeks of rehabilitation
- Occupation is a naturally occurring source of wrist movement, motivation and wellbeing that can be harnessed for therapeutic advantage after surgical repair of distal radius fractures
- Therapists can collaborate with patients to select and modify daily activities and occupations to incorporate into early postoperative therapy programmes

7.2.2 Introduction

A fracture of the distal radius is a common upper extremity injury frequently treated by surgical repair, followed by wrist mobilisation within two weeks of surgery (Quadlbauer et al., 2020). Wrist stiffness, pain, and functional or sensorimotor impairment can persist after surgery (Chung & Haas, 2009; Egol et al., 2014; Karagiannopoulos et al., 2013) and rehabilitative strategies that address impairment and promote early recovery are needed. Wrist and forearm exercises are routinely used during early rehabilitation to promote movement (Naughton & Algar, 2021; Quadlbauer et al., 2020). Performance of daily activities can also be used but is poorly defined as a rehabilitative strategy and not as widely promoted as exercise interventions (Collis et al., 2020a). One of the barriers to occupation-based interventions is a lack of knowledge about how occupation facilitates recovery from injury (Colaianni & Provident, 2010; Daud, Judd, et al., 2016a). Without such understandings it is difficult to design interventions that capitalise on the benefits of occupation.

In this study occupation refers to the broad categories of daily life engagements by which people occupy themselves: daily living activities, rest, education, work, leisure, and social participation (Amini et al., 2014). Occupation assumes meaning, purpose, intentional engagement and that occupation is contextualised within daily life (Amini et al., 2014). The term activity is used differentially to refer to the smaller actions or sets of day to day living tasks that occupations are constructed from (Amini et al., 2014; Polatajko et al., 2004). Performance of activities and occupations may facilitate recovery in ways distinct from exercise routines such as augmenting movement quantity and quality (Colaianni & Provident, 2010; Collis et al., 2020b), enhancing motivation, and facilitating functional movement (Colaianni & Provident, 2010). It was considered that performing daily activities may be an underutilised rehabilitative strategy. The questions were raised: what role does activity and occupation play in the recovery from distal radius fracture surgery, and how might occupation be harnessed to form a therapeutic intervention?

The Medical Research Council recommends that intervention development may require primary research to identify how that intervention is likely to produce change (Craig et al., 2013). A study was therefore designed to explore the perceptions and experiences of people about how engaging in daily activities and occupations influenced recovery in the first eight weeks after surgical treatment of distal radius fracture.

7.2.3 Methods

A qualitative study using Interpretive Description methodology (Thorne, 2016c) and underpinned by a critical realist perspective, was undertaken. The Standards for Reporting Qualitative Research (SRQR) (O'Brien et al., 2014) were used to inform the design of the study. The study was approved by the Auckland University of Technology Ethics Committee (AUTEC) on the 29th July 2019, number 19/224. In this paper the term 'therapist' refers to an occupational, physical or hand therapist involved in the rehabilitation of upper extremity injuries.

Interpretive description is a qualitative methodology where researcher and participant work together to generate knowledge about clinical phenomena (Hunt, 2009; Teodoro et al., 2018). Critical realism guided the philosophy of the study by accepting that an objective, knowable reality exists but rejecting the notion that observed phenomena can be understood exclusively through stringent scientific methods (Fletcher, 2017; Yucel, 2018). The imperative for researchers guided by critical realism is to explore mechanisms and contexts, to understand not only if something works, but how it works (Fletcher, 2017; Nairn, 2012). Interpretive Description focused the study firmly on clinical practice, and critical realism provided a cohesive overarching framework.

7.2.4 Study setting and participants

Participants were recruited through private and public hand therapy clinics in Auckland, New Zealand. Figure 11 details the recruitment procedures. Potential participants were selected based on predetermined inclusion criteria (Table 9) and purposive sampling criteria (age, gender, ethnicity, pain, kinesiophobia, and finger stiffness), in order to obtain maximum variation of participant characteristics. A sample of 20-30 was estimated based on the concept of information power, where fewer participants are needed in a study with high information power (Malterud et al., 2016). We achieved high information power through a tightly defined aim, targeting participant characteristics, applying established theory, and rich dialogue and analysis (Malterud et al., 2016).

Figure 11

Study flowchart

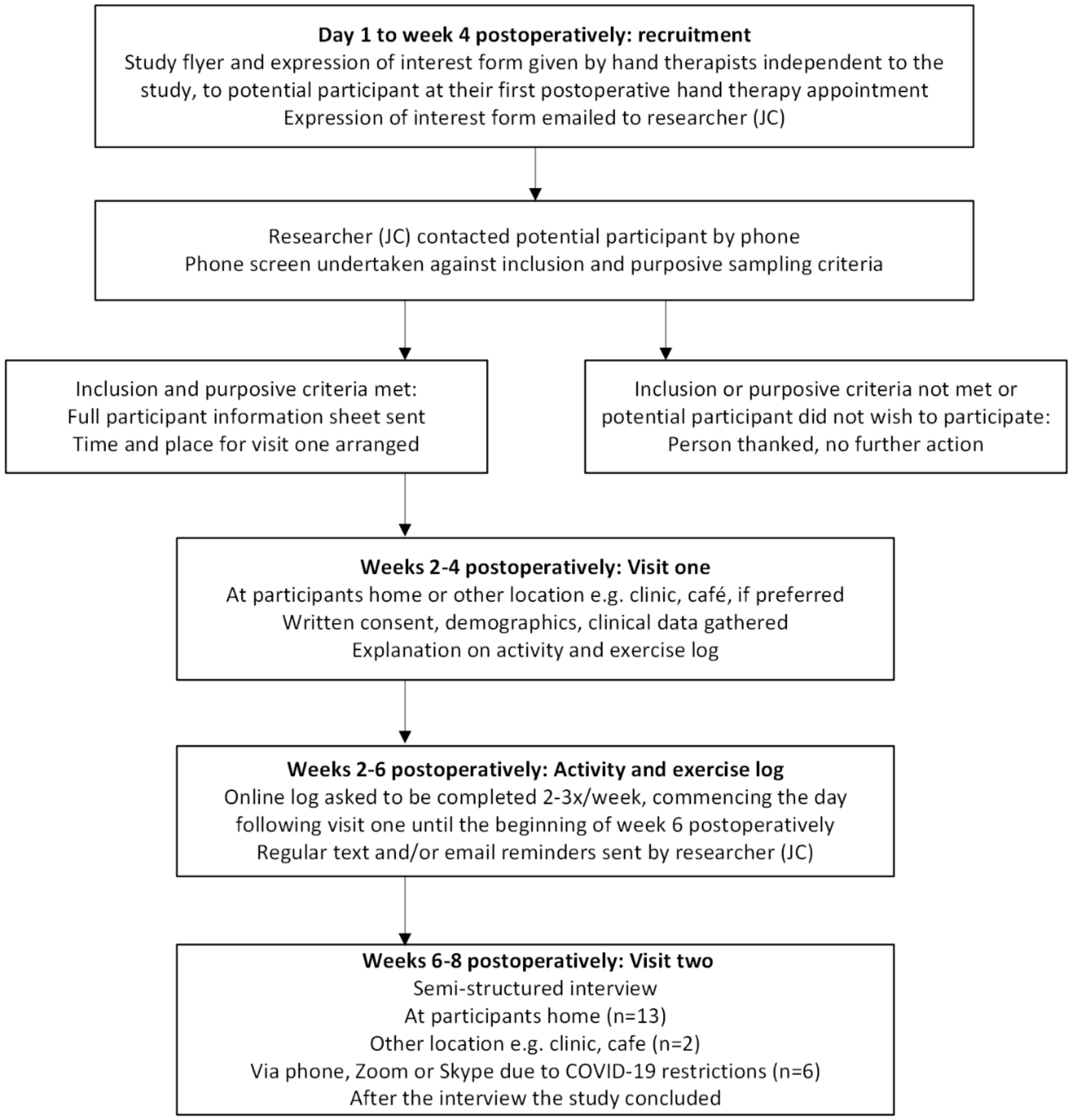


Table 9

Eligibility criteria

Inclusion
Aged over 18 years
Surgical fixation of distal radius fracture, all fracture AO types A, B, or C
Less than four weeks postoperative at time of recruitment
Stable fixation, deemed by surgeon to be suitable for mobilisation by four weeks
Conversational English
Exclusion
Concomitant fracture of another bone (excepting ulna styloid)
Concomitant surgery for injury of other tissues: tendon, muscle, nerve
Any condition or injury that significantly affects normal use of the operated limb
Patients undergoing hand therapy by primary researcher

7.2.5 Data generation

Data were generated via an activity and exercise log and a semi-structured interview. Participants were visited on two occasions (see Figure 11) The clinical features of pain severity and kinesiophobia were measured by the Patient Rated Wrist and Hand Evaluation (PRWHE) (MacDermid, 1996) and the Tampa scale of kinesiophobia-11 (TSK-11) (MacDermid, 1996; Woby et al., 2005) respectively. The TSK-11 has a score range between 11 and 44 with a score of ≥35 delineated as high kinesiophobia (Larsson et al., 2016). Wrist stiffness was scored as: >50%, 20–50%, or <20% of the contralateral side (Javed et al., 2015). Finger stiffness was a fingertip to distal palmar crease measurement >1cm (Egol et al., 2014).

Activity and exercise log

Between weeks two and six postoperatively, participants were asked to complete an online activity and exercise log (Appendix K). The purpose of the log was as a prompt for discussion during the interviews and to observe the types and range of activities that individuals performed. The log was developed from research that defined valued occupations and activity limitations for people with hand injuries (Eakman et al., 2010; Poulsen & Hansen, 2018; Wright-St Clair et al., 2012). Initially, participants were asked to complete the log daily; this was amended to two to three times per week as the first few participants indicated that daily completion was repetitive.

Semi-structured interview

The interview was conducted at between weeks six and eight postoperatively. The interviews were a semi-structured exploratory style (Manzano, 2016). An interview guide was developed around four broad areas: experiences of daily activities, perceptions on the influence of daily activities on recovery, advice/education received about activities, and the pragmatics of activity performance. The questions were open-ended and provided a framework only for the interviews. This approach allowed the interviewer to probe and to explore responses at a deeper level in accordance with Interpretive Description research (Thorne, 2016b).

7.2.6 Data processing and analysis

All interviews were audio-recorded and transcribed verbatim by a professional transcriber and checked for accuracy by the first author (JC). The data were analysed using reflexive thematic analysis, a six-phase inductive style of analyses that draws themes from the data (Braun & Clarke, 2006; Terry et al., 2017). Familiarisation was conducted by the first author through reviewing the audio recordings and transcripts. Codes were then generated inductively from the data, by (JC), using both descriptive and interpretive labels. NVivo 12 was used for the coding process. Following the completion of coding, theming commenced. First, candidate themes were developed, then discussed and finalised, based on agreement between all authors. Themes were subsequently named and defined.

7.2.7 Study rigour

The research team consisted of experienced therapists and academics. The first author (JC), an occupational and hand therapist, led data generation, coding and development of themes and was not involved in the clinical care of any participant. Cross-verification was achieved through the research team reviewing sections of data and confirming codes and final themes. Quality and rigour were promoted through a collaborative, reflexive approach. Epistemological integrity was achieved by framing the study within a critical realist ontology and Interpretive Description method. The steps of reflexive thematic analysis were followed to ensure a rigorous analytic process. It was acknowledged that the primary researcher may bring theoretical allegiances or professional assumptions that could influence the research (O'Brien et al., 2014; Terry et al., 2017) A presuppositions interview was conducted by senior researchers (VW and NS) prior to data collection. During the interview the primary researcher was questioned about assumptions and challenged to remain reflexive and alert to narratives that may reveal hidden meanings.

7.2.8 Results

During 2019 and 2020, 21 adults participated in the study. Participant characteristics are summarised in Table 10 and detailed in Table 11.

Table 10

Summary of participant characteristics

Variable	**Number (percentage) or mean (range)**
Gender: Female	14/21 (67%)
Age	53 (28-74)
Ethnicity: Māori	3/21 (14%)
New Zealand European	14/21(67%)
Other (Indian, Russian, Afghani)	4/21 (19%)
Dominant hand injured	10/21(48%)
Finger stiffness at visit one (>1cm ADPC)	11/21(52%)
Wrist stiffness at visit one (moderate or severe)[i]	16/21(76%)
Pain at visit one (PRWE pain sub-scale)	25/50 (10-41)
Kinesiophobia (TSK-11)	25/44 (12-42)
TSK-11 ≥35[ii]	2/21 (10%)
Fracture type: comminuted, intraarticular	19/21 (90%)
Ulna styloid fracture	8/21 (38%)
Volar locking plate	20/21 (95%)
Fragment-specific fixation	1/21 (5%)
Additional surgical procedure (2x carpal tunnel release)	2/21 (10%)
Number of days from surgery to mobilisation	13 (7-27)
Number of days from surgery to interview	53 (44-64)
Number of activity log entries	9 (3-23)

ADPC: active distal palmar crease; PRWE: patient rated wrist and hand evaluation; TSK: Tampa scale of kinesiophobia

[i] 20–50% (moderate), <20% (severe) range of movement of the contralateral side (Javed et al., 2015)

[ii] A TSK score of >35 is indicative of high kinesiophobia (Larsson et al., 2016)

Table 11

Characteristics of participants

Participant	Gender	Age	Injured side	Occupation	Intra-articular fracture	Surgical procedures	Finger stiffness[1] at visit 1
Paul	Male	55	Non-dominant	Handyperson, builder	Y	Fragment-specific fixation (radial, dorsal, ulna plates); CTR	Y
Farida	Female	50	Non-dominant	Storeperson	Y	Volar plate	N
Graeme	Male	46	Dominant	Plumber	Y	Volar plate	N
Angela	Female	51	Dominant	Homemaker	N	Volar plate	Y
Natalya	Female	59	Non-dominant	Homemaker; Administrator	Y	Volar plate & interfragmentary screw	Y
May	Female	32	Dominant	Landscape gardener; Parent	Y	Volar plate	N
Ian	Male	55	Dominant	Manager; Administrator	Y	Volar plate & radial pin plate	N
Layla	Female	34	Dominant	Parent	Y	Volar plate	N
Awhina	Female	49	Dominant	Driver	Y	Volar plate	Y
Zoe	Female	68	Non-dominant	Retired	Y	Volar plate	Y
Bill	Male	72	Non-dominant	Retired	Y	Volar plate	Y
June	Female	74	Non-dominant	Retired	Y	Volar plate	N
Kukurei	Female	56	Non-dominant	Music Teacher	N	Volar plate	N
Karen	Female	57	Non-dominant	Nurse	Y	Volar plate	Y
Santosh	Male	30	Dominant	Driver	Y	Volar plate	N

Marie	Female	71	Dominant	Retired	Y	Volar plate	Y
Silky	Female	71	Non-dominant	Retired	Y	Volar plate	N
Dina	Female	28	Non-dominant	Parent	Y	Volar plate & ulna styloid screw	Y
Alexa	Female	36	Dominant	Parent; Manager	Y	Volar plate & radial pin plate; CTR	Y
Trent	Male	62	Dominant	Handyperson	Y	Volar plate	Y
Nick	Male	55	Non-dominant	Designer	Y	Volar plate & dorsal pin plate	N

CTR: carpal tunnel release.

[i]Fingertip to distal palmar crease measurement > 1 cm

The activity log was completed an average of nine times (range 3 to 23). The majority of participants commenced the log by the end of week three (n=14) and the remainder during the following two weeks. The log and interviews revealed a broad range of activities performed without a splint during the first six weeks (Table 12). All participants were provided with a removable wrist splint (custom thermoplastic or off-the-shelf) at the time of mobilisation. The log showed that by the end of week three postoperatively most participants (14/21), were using their wrist during activities such as eating, showering, or grooming. Of those fourteen, many were also using their wrist during meal preparation, or household tasks. By the end of week six all participants were performing some personal, home, work or leisure activities involving their operated wrist without a splint.

Table 12

Activities and occupations performed by participants in the first six weeks with the wrist splint off and involving at least partial use of the affected wrist

Applying make-up, face, or hand cream	Opening cupboards, drawers, containers
Baby care e.g., diapers	Personal care e.g., shaving, brushing teeth
Childcare: dressing, pushing a pushchair	Pet care: feeding, grooming
Carrying light items e.g., a plate, lunch bag	Playing a musical instrument
Chopping, peeling vegetables	Playing video games
Cooking e.g., making breakfast or a salad	Sewing, using a sewing machine
Driving	Showering – washing and drying self
Eating, drinking	Swimming
Gardening e.g., weeding	Tidying up children's toys
Getting dressed, doing up shoelaces	Turning controls on kitchen appliances
Handcrafts	Unpacking and putting away shopping
Having a bath	Using a keyboard and/or computer mouse
Housework e.g., tidying, making beds,	Using a remote control
Laundry: Hanging up, folding, putting away	Vacuuming
Loading, unloading the dishwasher	Washing and drying dishes
Making a cup of tea or coffee	Washing, doing hair
Making roti	Watering the garden
Mopping the floor	Wiping benches

Interviews revealed that for most participants, daily activities and occupations were highly valued for facilitating recovery of movement and function of the affected limb. We generated five themes that elucidated how occupation acted as an agent of change in promoting recovery from surgical treatment of distal radius fracture. Quotes that are highly illustrative of the themes are presented. They are identified by participants' pseudonyms, ages and whether they injured their dominant (DHI) or non-dominant hand (NDHI). An overview of the themes is given in Table 13.

Table 13.

Five themes showing how activities and occupation influenced recovery from surgical treatment of a distal radius fracture

OCCUPATION operated	As a driver of recovery	Disruption to daily activities was experienced negatively Disruption motivated reengagement Daily activities were used to reclaim normality and enhance wellbeing
	Through offering ready-to-hand challenges	Daily activities were a ready source of automatic movement Daily activities had built-in gradations and challenges
	By inviting intentional doing	Intentional, conscious 'doing' was needed Mindful strategies were used to enable performance of activities
	To habituate the wrist to movement	Initial movement felt unnatural Activity performance normalised wrist movement Self-efficacy and confidence were enhanced by engaging in occupation
	Through drawing on psychosocial resources	Strength was gained from psychosocial resources Wellbeing practices were used to facilitate reengagement with valued occupations

Theme One: Occupation is a driving force of recovery

> *I just want life to go back to how it was. To be able to take the boat out and go fishing and ride my bike and stuff like that. Graeme, 46, DHI*

Theme one describes how the desire to return to valued occupations and life roles provided a potent impetus and focus for the recovery process. The disruption to daily life and usual activities and occupations was unwelcome. Participants expressed a strong need to reclaim independence, participate in usual life roles and return to valued occupations. Engaging in daily activities helped to reclaimed normality and wellbeing.

Experiencing disruption

> *Like I said, it's not until it didn't function, you realise how much you do use your hand. Awhina, 49, DHI*

Most participants talked about how routine activities previously carried out with little thought, such as getting dressed or making breakfast, were suddenly noticed and became sources of frustration, discomfort, and challenge. Many people expressed feelings of being lazy, or a burden. Others missed the 'ordinariness' of daily life and described the sudden loss of 'doing' as making them feel bored or lost.

> *Yeah, I'd get frustrated. Very frustrated. I'm not used to sitting still. I'm used to getting up and going. Silky, 71, NDHI*

There was a common experience that the interruption to everyday 'doing', negatively affected mood and wellbeing and some participants expressed fears about the future.

> *I was worried about what am I gonna be able to do again. I did ballroom dancing, and I was like always one day I thought to get back into it again and I was like, "Am I gonna be able to do it again?" "What am I gonna be able to do?" "How much movement am I gonna have?" Just those sorts of things. "What is my life gonna be like?". "When can I pick up my son?". Alexa, 36, DHI*

Reclaiming normality

The difficulties experienced motivated people to begin 'doing' again and use their affected hand. Initially this was often for simple functional activities, then later for work and recreational pursuits.

> *When I first tried to do it, it was like, "Oh my god, I can't even hold a cup of coffee." And it frustrated me so I got to the stage where I slowly built up so I could, over five days hold it and lift it. Graeme, 46, DHI*

> *We enter in a lot of things. Netball. Iron Māori. Amazing Race. But I couldn't even do the training. They wouldn't have me. It's like you've been outcasted … but it made me work harder. It made me wanna hurry up. Awhina, 49, DHI*

The need to re-establish normal routines and independence was expressed strongly. Some people described inactivity as being so foreign that the natural thing to do, was 'do'. Even if it meant taking more time or finding alternative methods, the very act of doing seemed to help combat the disorienting effect of the injury.

> *I think being able to do those things such that you are functioning in some degree of independence, I think that's important. Yeah, I think that's hugely important. Well, it was for me anyway. I hated the dependency. Absolutely loathed it. So, to be able to do those things and even if it took me forever, on simple tasks to start with, those kind of things were important. Zoe, 68, NDHI*

Engagement in meaningful occupations was seen to boost mood and wellbeing. Participants described feeling more settled when 'doing', that gardening lifted mood, or helping with household management negated feelings of laziness and uselessness. For some, starting to perform daily activities shifted the focus from 'I can't' to 'I can' providing a sense of optimism and hope.

> *Just to see the light at the end of the tunnel, to know that I'm gonna be able to use my hand. And to know that things will … come back to normal and … I'm gonna get better and I will get stronger, and I will be able to function properly again. Well maybe not function, but I'll be able to do the things I want to do. Nick, 55, NDHI*

Theme Two: Occupation offers ready-to-hand challenges

> *I thought well … I just have to work it out. You just have to work it out. There's nobody else here to do it for you, so you have to do it. If you don't do it, well you don't get any taties [potatoes] Silky, 71, NDHI*

This theme describes how activities and occupations promoted recovery through being ready and available. Activities and occupations were an intrinsic part of daily life thereby offering a naturally occurring source of movement and challenge. Activities were observed to have inbuilt gradations that created stepwise challenges for wrist movement.

A ready source of movement

> *The thing is that if I do anything, it's not that I think of it, it's just that I do it. That's just offhanded probably. You need to do it, do it.*

> *You don't even think like that, it's just such a natural thing. Bill, 72, NDHI*

The embedded existence of occupation in daily life was perceived to create a naturalistic opportunity for movement; in a sense, movement was a by-product of 'doing'. Occupation offered challenge in ways different from exercise routines. Exercises were done at specified intervals during the day and performed with focus. Activities and occupations, on the other hand, were thought to promote a more automatic type of movement that occurred opportunistically throughout the day as tasks that needed to be done presented themselves.

> *So, when I go to change dishwasher, I need to do it. I don't think it will develop my hand, I just set my mind that I need to come back to my usual duties and I think it's a normal thing. I don't think that it will be bending better… I do duties…and hand develop. Natalya, 59, NDHI*

Some participants noticed a naturally occurring rhythm of movement during activity that took their focus away from pain or discomfort.

> *Once you start doing what you enjoy, even if you do get little twinges here and there, you totally forget about it. You don't really pay any attention to it. If you keep doing whatever you enjoy and keep using your wrist, after a while you don't pay any attention to any little pain you get. Farida, 50, NDHI*

A natural stepwise challenge

Daily activities were perceived to offer challenges for movement that happened in a stepwise process. Participants started with simple tasks that involved minimal load or demand on wrist motion and progressed to greater challenge over time. Frequently people started activity performance by just using the fingers of the affected hand.

> *Even if I had the brace on and I wasn't confident with what was going on in my wrist, I'd still very much use my fingers. I was typing. Using the mousepad on my computer. Using my fingers to open, trying to open packets and yeah definitely using my fingers. Trent, 62, DHI*

Over time the wrist would be included for more of the activity and a broader range of activities were introduced. Sometimes this was a conscious process but often occurred with little thought, people simply noticed that they were using their wrist for increasingly challenging tasks.

> *I was conscious that it was changing very quickly day by day to sort of add a little bit more on each day and try something different. Maybe I couldn't do something one day, but I could do it the next day. Opening the shampoo bottle. I couldn't do it one day. Could do it the next day. Did it every day after that. Just things like that, you just kind of add what you can do to your repertoire and then just look for other things that you can do with it. Ian, 55, DHI*

Theme Three: Occupation invites intentional doing

> *I want to get back to automatically using my right hand without thinking. And I think that to do it consciously, first of all, is the first step in doing that. Marie, 71, DHI*

In this theme the influence of occupation on recovery is by intentional engagement. In contrast to theme two where movement occurred instinctually, it was perceived that deliberate choices were made to perform activities in order to promote movement, strength, and function. Mindful decisions were made about how to perform an activity.

Intentional use of affected wrist

Participants for the most part perceived that they needed to make a conscious choice to use their affected hand in order to make progress. There was a common perception that daily activities played a significant part in restoring movement and strength.

> *But yeah, in terms of recovery, like I'm just very blown away by how well I've come along and yeah, I certainly do believe that that bit extra that I've been doing with my wrist, changing nappies, and chopping things and a little bit of gardening and that, I definitely think it's helped to get me where I'm at now with that movement. May, 32, DHI*

Many people spoke about how they looked for opportunities to use their affected hand. There was a conscious seeking out of bilateral, challenging, or unfamiliar tasks in order to intentionally promote use.

> *But I made a real effort to try and do any fine stuff with my right hand. Your hand's been sitting around not doing anything for a*

> *while, it gets lazy, your left hand takes over. So, there's a lot of things that I would try and do with my right hand. Making a cup of coffee. Maybe hold jars with my left hand and do the lid with my right hand and spoon it out with my right hand. Do the dials and knobs on the coffee machine with my right hand. Ian, 55, DHI*

Most people noticed an immediate improvement in wrist movement and function once regular activity performance was initiated.

> *You take the brace off, you do your exercises… and then put the brace back on. So… you're actually not using it a lot the rest of the time…And it's actually better to be able to use it all the time. I think, becoming easier because I'm using it all the time, rather than having it in the brace and only using it for little bits of the time. Angela, 51, DHI*

Developing strategies to determine level of activity

Bounded by a desire to get better but not wanting to cause harm, participants used multiple strategies throughout the day to decide whether, and how to, perform an activity. People commonly used strategies such as tentatively trying an activity to test the wrist, simplifying an activity, or only using their wrist as a support. Many times, participants discovered they managed better than expected thereby gaining confidence and a willingness to repeat an activity or try something harder.

> *Well, I thought I'd try. I thought, "Okay, I'll try and bathe the dogs. If it doesn't work they can airdry." But they're pretty good so they just stand there. I don't have to really do a lot. So that was alright and then when I went to pull the weeds out, well if it wouldn't come and it just felt it wasn't going to come, I gave that away. I tried to do things and if it worked it worked. If it didn't it didn't. Silky, 71, NDHI*

If an activity caused pain, discomfort, or fatigue this was taken as a cue to perform the activity in a different way or wait for a few days before trying again.

> *When it felt like it was aching or tired, I would just put the splint back on again. It wasn't out of it for that long, but probably, yeah definitely more than what they had suggested. May, 32, DHI*

For some participants who were more fearful of movement, functional activity often resulted in pain and was taken as a cue to rest and wait.

> *They [hand therapist] wanted me to start using it," but it was just too sore. Because as soon as you move it, all this starts hurting … I had it [the splint] off for a few hours, but man it hurt. And so after that I put it straight back on and kept it on. In my particular case it wasn't ready. Trent, 62, DHI*

Many people relied on advice from health professionals to guide them about daily activities. While some participants received helpful education about daily activities, many said information was confusing, conflicting, or absent, and was perceived as an inhibitor of progress.

> *When I came home, I kept thinking can I do this, or can I do that, like for example, can I chop the onion, or can I cook, or can I get a shower properly and use my hand? … I told myself to keep doing it anyway, 'cause no one told me to do it or not. They should explain if it's good for my wrist to do it, or if it's bad, then not to do it. Layla, 34, DHI, (paraphrased for understanding)*

Some participants felt that using their wrist in the early weeks was too soon, others thought that everyday doing was an expected part of rehabilitation over and above exercises. Several participants however said that more direct advice on activity performance would have been helpful for enabling reengagement in daily life and for enhancing their recovery.

> *I would say so. They pretty much just give you the hand exercises and that's it. And I think if they gave us on what we can do with that hand, where it's like if you're using your wrist you can flick your hand to make your bed or something. Something like that. I reckon that would help a lot. It'll make everyone's recovery faster. Dina, 28, NDHI*

Theme Four: Occupation habituates the wrist to movement

> *The more I do, the more I can do. Alexa, 36, DHI*

Theme four describes how occupation facilitated recovery of automatic, instinctual wrist movement. Initial experiences with movement were often unpleasant and provoked apprehension. Performing daily activities acted to normalise wrist movement, build confidence, and progress the wrist towards unconscious use.

Experiences of moving and using

When participants began forays into wrist movement there were common experiences of apprehension and fear of causing harm. While some people felt confident to use the affected hand, most were cautious and took a tentative approach.

> *Well it was a bit scary at first. The pain and that, yeah like I said it, didn't feel quite right to do, May, 32, DHI*

Participants frequently described movement as feeling awkward, robotic, unnatural, or weird. Some people described that movement lacked spontaneity and had to be relearned. Other participants described unpleasant somatic sensations in the wrist.

> *It just feels, instead of having elastic bands in there [the wrist], it feels as if you've got cord. Tight cord...it feels like there's, instead of nice stretchy rubber bands, someone's replaced those rubber bands with tight cords. Zoe, 68, NDHI*

Many participants said that it required focussed effort to use the affected hand. There was a sense that the hand had become lazy, and the non-injured hand would simply take over. Some were worried that if they didn't force themselves to use the wrist, they might never recover full use.

> *There was a resistance you know initially when I would do a task and sometimes you just kind of like feel lazy, want to use the other hand, which is more in motion. Santosh, 30, DHI*

Alongside these negative experiences participants also liked moving the wrist again. There was a sense of relief at being able to use the wrist, often associated with a feeling of moving forward with rehabilitation.

> *Once the brace was off, now it's just like, yeah instantly starting to, my brain was like, "Okay that is an available limb for use again." Alexa, 36, DHI*

Activity performance normalised wrist movement

Woven through the interviews was a common noticing that the more an activity was repeated the easier and more familiar movement became.

> *At first, I just couldn't do it. I was like oh my god, but then I just kept doing it and now I can. Karen, 57, NDHI*

Participants often spoke about how initially they had to push themselves through some discomfort. There was an expectation that some degree of pain was inevitable but that by slowly pushing through pain, progress would occur.

> *Initially when I'm doing a task, it's a bit painful and the resistance is there, so…I had to push myself a bit, so my wrist gets used to the situation. Like, if I brush my teeth or take shower…or apply the moisturiser, the resistance was there. But if I…overcame it with tolerating a bit of pain and pushing myself a bit…next time the wrist was used to the situation and … it was better than before. Not so hard, I would say a bit easier. Santosh, 30, DHI*

Many participants expressed the idea that repeating everyday activities had a positive effect on their confidence and self-efficacy. There was a noticing that succeeding with a simple activity was empowering and built confidence to try something more difficult.

> *It seems to me that by finding out that you could do that, that you were kind of surprised and that you could do it, that builds a bit of confidence in terms of trying it again another time. Or trying something a little bit harder. June, 74, NDHI*

Theme Five: Occupational reengagement draws on psychosocial resources

> *I think it's a journey two ways. I think you've got a physical one and you've got a mental one. And if the mental one's not on board then you're not going forward either. Zoe, 68, NDHI*

Theme five describes the concept that recovery required mental focus and a drawing on a range of psychosocial resources. Previous experiences, personal strengths and wellbeing practices were harnessed to enable re-engagement with life activities. The theme encompasses the notion that both body and mind strategies were needed for the rehabilitation journey.

Personal strengths and previous experiences

Many people spoke about how they used positivity and optimism to overcome apprehension about moving and using the wrist. Other people described how determination would make them persist even when things were difficult.

> *In some ways I think the recovery of my wrist is a lot to do with the attitude of stubbornness and pig-headedness. Bill, 72, NDHI*

Many participants expressed a strong sense of self-belief about their ability to recover from the surgery. This often came from previous life experiences that had built hardiness and resilience such as growing up on a farm or being widowed. A number of participants spoke about their pragmatic, 'just get on with it' attitude or a choice to focus more on the "can do's" and less on the "can't do's".

> *I used to be able to do this so I can jolly well do it now. June, 74, NDHI*

Recovery was not all about pushing the boundaries. Some participants said they had to adjust expectations and allow their body to do the work of recovery, that overly high expectations about recovery was not helpful.

> *At the beginning I thought, "Why I cannot do this? It should be that I can do it". Now I stop thinking like that. Everything changed, I needed to reset my mind. And now it's much easier to accept what I can do and what I cannot do. I don't press myself. I have no expectations. I'm happier now. Natalya, 59, NDHI, (paraphrased for understanding)*

Wellbeing practices

Participants also used wellbeing practices to cope with the injury and disruption to daily life. Some people used gratefulness to affirm their progress, some looked for the 'silver lining' and others challenged negative ideas about pain.

> *It was a little bit hard at first. The exercises were really sore because I have to twist my hands everywhere. But I did it anyway because I was thinking, the more sore, the more it was good for me. After that I was able to do stuff and everyone says to me your recovery is so fast, because I kept using my wrist and was doing. Layla, 34, DHI*

Other people expressed that exercise, good diet and maintaining social interactions were beneficial for healing. Some used mindfulness practices such as meditation or listening to music. These participants spoke about how such practices helped to maintain a positive energy to the healing process.

> *Absolutely. It has to be, doesn't it? If we're stressing about something and negative about it, then the healing's not gonna happen. And I kind of just intuitively know that with anything that we've really got to change our mindset, like I was doing meditations on healing and having a positive, sort of imagining it healed. I thought was very helpful. Kukurei, 56, NDHI*

7.2.9 Discussion

Our study explored how engaging in daily activities and occupations influenced recovery in the first eight weeks after surgical treatment of distal radius fracture. Participant narratives suggested that occupation is highly influential in promoting recovery of movement and function after such surgery. Informed by the data, we outline a novel framework to elucidate how occupation acts to improve movement through acting as a driving force, offering ready-to-hand challenge, inviting intentional use, habituating the wrist to movement, and by drawing on the psychosocial resources of individuals. Our study deepens understandings of the remediating effects of activity performance in the early postoperative period. Insights that may challenge the traditional focus on exercise as the predominant therapeutic intervention are offered.

The study suggests two areas of focus for clinical practice: understanding occupation as an agent of change and viewing occupation and exercise as synergistically beneficial.

Occupation as an agent of change

We found that a key action of occupation in influencing recovery was by promoting both automatic and intentional wrist movement. While the idea that activities and occupation promoted wrist movement may seem an intuitive finding, we believe it provides a key to understanding occupation-based approaches. Unlike exercise routines which required focused attention and were performed intermittently, daily activities appeared to promote movement in low doses throughout the day. Participants also performed a broader range of activities than may be traditionally expected during the early weeks of recovery. The repeated wrist motion promoted through these activities may produce greater volume of movement than recognised and help to explain the benefits of approaches that include activity performance (Collis et al., 2020a).

Some participants described a considerable wariness about activity due to advice about what they shouldn't do rather than an enabling focus on what they could do. Recent literature has suggested that therapists may be more wary about daily activities than necessary after volar plating of a distal radius fracture (Quadlbauer et al., 2020), and the avoidance of activity early after surgery has been challenged (Collis et al., 2020a; Quadlbauer et al., 2020). In our study, participants performed a wide variety of activities, modifying the manner of performance according to postoperative timeframes and perceived capability. Participants made reasoned and agile decisions throughout the day about activity engagement, self-modulating their activity performance by using pain, fatigue common sense, and a 'try-it-out' approach as a guide. Even participants that were less cautious, tempered their level of activity engagement in order to avoid pain and swelling.

It is important to remember that the risk of harm from underuse is likely much greater than that of overuse (Mehta et al., 2011). Poor self-efficacy and kinesiophobia are predictors of worse outcomes after distal radius fracture (Björk et al., 2020; Mehta et al., 2011). Interventions that promote self-efficacious behaviours are advocated as a way of avoiding disuse and fear-avoidance (Dewan et al., 2013; Mehta et al., 2011). Achieving mastery of small activities early after surgery may help to mitigate guarding and kinesiophobia (Hamasaki et al., 2018), promote early self-efficacy and create a platform for introducing progressively more challenging activities.

In our study, splint use was highly variable between participants and over time, and this may have influenced wrist stiffness and pain. Some participants reported that splints were appreciated for support and pain relief but many disliked splints because they impeded movement. Frequently, participants removed the splint simply to enable them to carry out daily activities and allow uninhibited wrist movement. The decision as to whether to remove a splint appeared to be based on varying postoperative advice and the degree of confidence of each participant. The relationships between postoperative advice, splint wear and wrist stiffness should be investigated in future research.

We observed that activity performance appeared to positively influence wrist movement through habituation. Habituation, a form of neuroplasticity, is a decreasing response to a repeated benign stimulus, whereby people can progressively filter out attention to irrelevant stimuli (Podoly & Sasson, 2020; Siengsukon, 2012). In our study, this appeared to occur through repetition. Participants frequently experienced initial movement as unpleasant, but repetition of a task or activity resulted in a reduction of unpleasant sensations and a normalisation of wrist movement. Habituation through occupation may work similarly to graded exposure where the incremental introduction of noxious stimuli reduces hypersensitivity or pain response (den Hollander et al., 2016; Hamasaki et al., 2018). Other mechanisms of occupation may be through diversion from pain (Colaianni & Provident, 2010; Nelson et al., 2002) or the greater efficiency of functional task performance versus exercise routines in promoting motor learning (Boudreau et al., 2010; Valdes et al., 2014; Westlake & Byl, 2013). Educating patients that repetition of activity will lead to normalised wrist movement may help patients overcome the hurdle of initially unpleasant movement.

Our study also elucidated the scope of occupation in promoting recovery beyond that of inducing movement. There were psychological and social mechanisms at work. Fisher (2014) discusses how engagement in occupation can have simultaneous actions of experiencing pleasure, productivity and restoration, a finding supported by our study. Our participants experienced the restorative effect of joint movement through doing, while also feeling productive, optimistic and a welcomed sense of normality when doing. The desire to return to valued occupations acted as a strong driver during early rehabilitation constantly propelling people forward towards greater use of the affected wrist.

Occupation and exercise as synergistic interventions

Occupation as a therapy may be underutilised as a therapeutic strategy in early surgical distal radius fracture rehabilitation. Currently, the predominant approach tends to endorse exercise, but constrain activity during the first six weeks (Collis et al., 2020a; Quadlbauer et al., 2020). We propose that occupation and exercise be advocated as synergistically safe and beneficial during the early weeks of recovery. It is suggested that such an approach would be empowering for patients, fostering earlier independence and wellbeing (Robinson et al., 2016), and facilitate wrist movement beyond the scope of exercise routines.

Viewing activity performance as a means rather than merely an end goal (Gray, 1998), is likely to represent a reversal in the way daily activities are perceived by many therapists and indeed, patients. Rather than solely perceiving daily activities as something patients do once they have regained sufficient capacity, purposeful activities can be seen as a remediator of movement. In order to make such a shift, occupationally-positive language that advocates safe and beneficial performance of daily activities would need to be adopted.

Through a practical lens, performance of daily activities could be included in home programmes, framed as a structured part of rehabilitation. Patients could be educated on intentionally performing tasks and activities that will provide a 'just-right' (Gray, 1998; Price & Miner, 2007) level of challenge. Education should highlight how daily activities also promote automatic movement through being ready-to-hand. Activity grading and self-regulation of activity performance could be taught in order to ensure that activities are commensurate with the stage of healing (Perlman & Bergthorson, 2017).

In addition, clinicians could promote the use of psychosocial strategies that participants used in this study such as optimism or problem-solving skills. Other strategies were focussing on the 'can dos' rather than the 'can't dos', using resilience gained from previous experiences, determination, positivity, and wellbeing practices. Engaging in activities and occupations was also reported as improving mood and wellbeing. This finding links strongly with the principles of positive psychology, where the building of capabilities rather than a direct alleviation of anxiety or negative cognitions is the focus of treatment (Carr et al., 2020; Müller et al., 2016). Therapists could incorporate positive psychology strategies by helping patients to identify and harness psychosocial resources that enhance recovery.

Strengths and Limitations

A key strength of this study is that participants were interviewed early after surgery, while still immersed in the recovery journey. A unique perspective situated in the social and health care context of Aotearoa, New Zealand. was gained. The study brings a cross-disciplinary lens, propelling occupational and physio-therapists towards a greater understanding of the complimentary role of occupation and exercise. The study analysed narratives of 21 diverse participants but may not represent experiences of people from different social, cultural or rehabilitation settings. Participants were not offered the opportunity to check the transcripts so the interview narratives must stand in their own right. Only one author conducted coding and initial theme development which may have resulted in a narrow interpretation of the data. This was mitigated by reflexive data analysis and regular author collaboration.

7.2.10 Conclusions

The study explored the ways that activities and occupations influenced recovery from surgical treatment of distal radius fractures. Participants highly valued daily activities for promoting recovery in the first eight weeks after surgery. Activities and occupations were found, subjectively, to be a strong driver of the rehabilitation process, positively influencing recovery through promoting wellbeing, wrist movement and habituation. The study challenges therapists to use activities and occupation as a substantial source of movement that can be exploited for therapeutic advantage. A postoperative approach that promotes occupation and exercise as synergistic interventions has the potential to result in improved outcomes and an holistic rehabilitation firmly centred on the individual. Future research that evaluates wrist movement during purposeful activities is planned. Data from the current and future studies can inform development of occupation-based interventions.

7.2.11 Declaration of Interest

The authors report no conflicts of interest

7.2.12 Acknowledgements

The work was supported by research grants received from Counties Manukau Health, Hand Therapy New Zealand - Ringaromi Aotearoa, and Occupational Therapy New Zealand - Whakaora Ngangahau Aotearoa.

7.3 Chapter conclusion

Chapter 7 presented the published article of an ID study that explored patient perspectives and experiences on how engaging in daily activities and occupations influenced recovery during the first eight weeks of rehabilitation. Although previous studies reported on patient experiences of early rehabilitation (Bamford & Walker, 2010; Watson, Martin, et al., 2018), such studies did not seek to explore the particular role of activity and occupation in bringing about change. The study produced new knowledge about the mechanisms of activities in facilitating improvements in the affected wrist, in ways that differed from exercise routines. Participants performed a greater range of activities in the early weeks of recovery than previously reported and demonstrated an intuitive ability to modify and adapt activities so they could be performed safely. The study elucidated that an important mechanism of activity was the multiple, readily available, opportunities for wrist movement that occur during daily activities. Activity and occupation provided naturally occurring gradations in challenge for the wrist and repetition of activities habituated their wrist to movement. Participants felt better when engaging in the activities that mattered to them and described detrimental effects on their wellbeing when unable to participate. Psychosocial resources such as optimism, motivation, and a sense of accomplishment were all enhanced by performing activities.

Data from study III was used to inform aspects of the design of study IV. Prior to study III, it was unclear what activities would be suitable to measure in the quantitative study or whether participants would be able to self-select purposeful activities. The list of activities performed by participants (Table 12) was used as a basis for the list of suggested activities in study IV.

Chapter 7 concludes phase two of the thesis. Having firmly established the value of daily activities during early rehabilitation I was now interested in evaluating movement during purposeful activities. The following two chapters present a motion analysis study of wrist movement during daily activities and exercise repetitions.

Chapter 8 Study IV: Measurement of wrist movement during daily activity

8.1 Chapter overview

The next phase of the research was a motion analysis study designed to test the hypothesis that daily activities could elicit quantity of movement greater than, or similar to, exercise repetitions. To inform the design of the research a review was undertaken to explore technologies that would provide a suitable measurement of real-world movement. Chapter 8 presents an overview of contending technologies and discusses why electrogoniometers were selected. Chapter 9 presents a manuscript for study IV.

The potential technologies for study IV were motion capture systems, accelerometers, garment based wearable sensors, and electrogoniometers. For each method, the technology will be described, validity discussed, and advantages and limitations pertinent to study IV debated.

8.2 Motion capture systems – marker-based

Three-dimensional (3D) motion capture systems are generally considered the gold standard of motion analysis. Usually in 3D motion capture, reflective markers are affixed to the body, and cameras are used to record movement with direct line of sight from the marker to the camera (Kontaxis et al., 2009; Murgia et al., 2004). Motion is filmed, and data analysed computationally using systems such as VICON, Qualisys or OPTOTRAK. Placement of markers is generally based on the joint coordinate system recommended by the International Society of Biomechanics (ISB) (Wu et al., 2005).

8.2.1 Validation

3D motion capture has been validated for measuring wrist motion during daily activities and is widely used in research. Studies have used 3D motion capture to quantify wrist range of movement requirements during daily activities (Aizawa et al., 2010; Gates et al., 2016; Taylor et al., 2018; van Andel et al., 2008), to evaluate compensatory wrist movement after injury (de los Reyes-Guzmán et al., 2010;

Kasten et al., 2009) and to compare simulated and functional upper limb activities (Taylor et al., 2018).

Evaluation of reliability and validity of motion capture has been conducted against fluoroscopy, steroeradiography and goniometry. Hillstrom et al. (2014) tested the validity and reliability of 3D motion analysis in measuring wrist movement, initially on 10 cadavers. Fluoroscopy was used as the reference test, and measurements were compared against electronic and manual goniometers. Motion analyses was more accurate than manual goniometry ($p<0.005$) but not electrogoniometry, ($p=0.066$). Small et al. (1996), tested the accuracy of a 3D system in evaluating wrist movement against steroeradiography, showing high correlation between the two systems.

8.2.2 Advantages and limitations

Motion capture was considered when deciding whether to conduct the study in participant's homes or in a laboratory. Motion capture would have allowed high quality measurement of wrist motion across a broad range of motor performance metrics such as joint angles, duration of activity, velocity, trajectory, and acceleration (Lee & Jung, 2015; Valevicius et al., 2018). Protocols have been developed for the measurement of wrist movement during functional activities (Brigstocke et al., 2014; Li et al., 2005). A major drawcard was that the university through which this research was undertaken, has a 3D motion laboratory and extensive expertise in the use of this technology, thus negating the need to invest in expensive alternatives. Other advantages were that markers adhere easily to the skin, do not interfere with joint movement, and do not impede sensory feedback from the palm, or fingertips. Considerable thought was given to whether I could undertake study IV using motion capture due to the availability of such high-quality technology.

A main drawback for motion capture systems was the need for the study to be laboratory-based. For study IV, although daily activities could be set up in a laboratory, this was contrary to the nature of the study where the aim was to measure wrist movement as it occurs in the context of everyday life (see 2.3 and 4.3 for explanations on the importance of a naturalistic setting). Another limitation was that 3D motion systems are best suited to measuring short duration activities. For example, the processing of data from five minutes, can take hours to process and may, in some cases, cause systems to fail (R. McLaren, personal communication, October 15, 2018; A. Bruder, personal communication, 23 October 2018). For study IV, I was planning ten minutes of continuous recording, making 3D motion capture problematic to use. Additional limitations may have included soft tissue artefact where skin moves over rigid bony anatomical landmarks requiring complex computational correction and the loss of data due to markers loosing direct line of sight during performance of some daily activities (Aizawa et al., 2010; Taylor et al., 2018).

8.3 Motion capture systems – markerless

Alternative camera systems which do not use reflective markers have been developed. These systems can be used to capture motion in a range of real-world environments. They include optical tracking devices which use cameras and infrared light detecting systems such as Leap Motion (Elliott et al., 2017), Microsoft Kinect, Creative Senz3D (Pham et al., 2015), or the Camera Wrist Tracker (CWT) (Shefer Eini et al., 2017) to track hand and wrist motion.

8.3.1 Validation

Leap Motion has been validated for wrist motion, against the gold standard of motion capture (Smeragliuolo et al., 2016), magnetic motion capture (Elliott et al., 2017) and an inertial measurement unit (Nguyen et al., 2015). Smeragliuolo et al. (2016) simultaneously tracked wrist movement using Leap Motion Capture and a marker-based motion capture system. There was high correlation for wrist flexion/extension (r=0.95) and radial/ulnar deviation (r=0.92) but not for pronation or supination (r=0.79). Elliott et al. (2017) found no significant differences for the two systems for wrist flexion, extension, ulnar and radial deviation, and supination. In accordance with the findings of Smeragliuolo et al. (2016) pronation was less accurate with Leap Motion technology, underestimating end range. Nguyen et al. (2015) compared Leap Motion against accelerometry finding correlation coefficients above 0.95 for wrist flexion, extension, radial and ulnar deviation.

8.3.2 Advantages and limitations

Markerless motion capture systems have the advantage of not needing sensors to be attached to the limb. They use an optical sensor, containing infrared emitters and small cameras, above which the hand is placed, and moved (Nizamis et al., 2018). Data is processed and analysed computationally (Pham et al., 2015). This may have greater acceptability and use with patients who have had an injury or surgery, who may be intolerant to tight fitting garments or wearing of reflective markers. It is reported that markerless systems are less expensive and that assessments can be performed quickly (Nizamis et al., 2018).

While these systems may allow measurement of daily activities in home or work environments, a disadvantage of the Leap Motion technology is that wrist motions must be performed over a stationary sensor, with the forearm resting in a support. This limits the distance that the arm could move away from the sensor and the range of activities that could be assessed. Nizamis et al. (2018) found that for optimal tracking, the hand had to be kept above the sensor at a distance of 14-24cm with the arm cradled in a specially constructed arm support. Additionally, the use of objects commonly used during daily activities, may interfere with data acquisition. Another system, Kinect, is primarily used to track full body motion with less use for measurement of wrist or finger movement (Pham et al., 2015).

Commercially available products and analytic software were not available at the time of study design, making field-based motion capture systems complex to use for study IV.

8.4 Accelerometry and Inertial Measurement Units

Accelerometers and IMUs, often referred to as activity monitors, have traditionally been used to measure gait but are gaining popularity for monitoring upper limb activity (Bailey et al., 2014; Lawinger et al., 2015). They are small electronic devices that can be worn like a wristwatch to measure changes in speed with respect to time (acceleration). Force sensors detect movement and give and output, known as an activity count (Yang & Hsu, 2010). They are small devices which attach to the arm and allow for uninhibited motion and activity. They are therefore well-suited to objective measurement of dynamic body motion in real-world environments (Bruder et al., 2018; Hayward et al., 2016). Inertial measurement units (IMUs) are sensors comprised of an accelerometer, to measure velocity, a gyroscope, that measures orientation and angular velocity, and a magnetometer, used to detect orientation relative to north. Many modern accelerometers contain IMU sensors, as opposed to an accelerometer sensor alone, and are capable of measuring position, velocity, and complex joint motion simultaneously (Nguyen et al., 2015; Wang et al., 2017).

Accelerometers can measure various parameters of motion. Magnitude can be calculated by totaling activity counts during a given period of time (epoch). Duration, or time when the upper limb was moving is achieved by recording the sum of all epochs from a minimum threshold of activity counts. Movement ratios between limbs can be determined by wearing an accelerometer on both limbs (Bailey et al., 2014).

8.4.1 Validation

Accelerometry is well-established for upper limb activity monitoring, but fewer studies have validated accelerometry for wrist range of movement (Vega-Gonzalez et al., 2007). IMU sensors have been compared against robotic simulations, 3D motion analysis, and goniometry (Álvarez et al., 2016; Fantozzi et al., 2016; Kumar et al., 2015; Robert-Lachaine et al., 2017). A systematic review showed that wearable sensors could achieve error rates of <5% for wrist movement but only with high levels of customization to software (Walmsley et al., 2018).

8.4.2 Advantages and limitations

The primary benefit of accelerometers is that they can be worn in virtually any environment. They lend themselves well to being able to measure wrist motion at home, work or during recreational activities. They are small, can be worn like a wrist watch and do not interfere with joint motion (Lang et al., 2017). They are relatively inexpensive and can monitor movement over long durations, which is not possible with 3D motion capture.

To measure wrist joint angles, an accelerometer would need to be worn on both the forearm and hand, and differences between the relative orientations and acceleration calculated, via a sensor fusion algorithm, to give joint angle estimations (Álvarez et al., 2016) . While technically possible, there are considerable challenges in using the technology in this manner, and it is considered that the ability of accelerometers to measure wrist motion during daily activities is reaching the limits of what the sensors are able to do (M. King, personal communication, December 6, 2018).

Accelerometers may not be able to accurately differentiate types of activities or movements for example between sweeping the floor and arm swinging when walking. Nor can they distinguish between types of activity e.g. eating versus brushing hair (Bailey et al., 2014) and may not be able to classify intensity of activity with sufficient accuracy (Dobkin, 2013). Wrist worn accelerometers may miss small movements of the wrist and hand and underestimate the actual amount of arm activity that occurs during activity (Bailey et al., 2014). This was a problem encountered by Bruder et al. (2018), who were able to accurately measure activities that required gross arm motions, such as stacking a box on a shelf, but inaccuracies were observed with obtaining data when typing on a computer.

For study IV where I wanted to accurately measure joint angles the technical challenges of accelerometers precluded their use.

8.5 Wearable stretch sensors

An alternative wearable technology is e-textiles where the electronic circuitry is embedded within fabrics (McLaren et al., 2016). The fabrics are made into garments such as gloves such as those in Figure 12. The sensors in the fabrics are reactive to mechanical deformation. When extended or contracted by joint motion, resistance or capacitance of the sensors changes and data outputs can be converted into joint range of motion measures (Han et al., 2018; Huang et al., 2017; McLaren et al., 2016).

Figure 12

StretchSense smart glove fabricated for hand motion capture

Note. Retrieved from https://www.stretchsense.com/product/smart-glove/

8.5.1 Validation

Substantial development work has been done for the measurement of finger motion (Rashid & Hasan, 2018; Saggio, 2014), but less so for the wrist, largely due to the complex, multiple degrees of freedom associated with movement of the wrist (Huang et al., 2017). Papers are emerging on wrist measurement (Huang et al., 2017), but commercial products and research in health rehabilitation settings is limited and lacking in validation (Gentner & Classen, 2009; Wang et al., 2017).

8.5.2 Advantages and limitations

The technology of e-textiles holds promise as it has the advantage of ease of wear, and the ability to simultaneously measure multidirectional motion. The garments could be worn during everyday activities in home and work environments, and could conceivably be worn under a wrist orthotic, which is usually a requirement following wrist surgery.

As this technology is relatively new with respect to rehabilitation applications, there are a number of technical challenges. These include slippage of the garment during motion and poor accuracy at high velocities (McLaren et al., 2016; Rashid & Hasan, 2018). The need to have a tight fitting garment to avoid slippage would be problematic for a post-surgical population and a glove would inevitably inhibit normal sensory input from the palm of the hand.

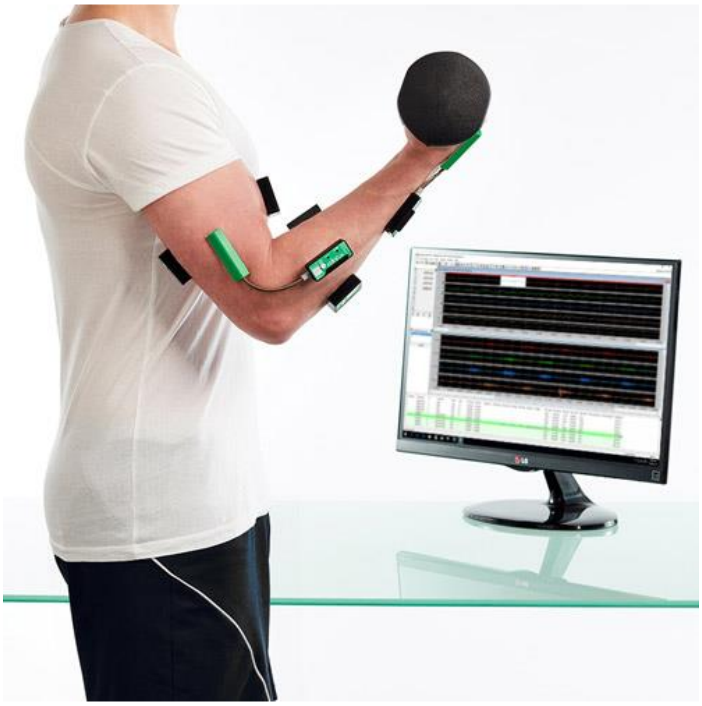
There was considerable appeal in using wearable gloves for my study due to the potential accuracy and lack of confinement of activity types and study locations. There is a company in Auckland that manufacture such garments and I met with a sales representative to discuss the feasibility of using gloves. The main factor that precluded me using this technology was that the garments and software would have required extensive development work. The expense and technicality of this was outside the scope of this thesis.

8.6 Electrogoniometry

Electrogoniometers are small, low profile electronic devices that are attached to the skin to track dynamic joint movement. They allow unrestricted joint movement and are suitable for measuring motion during a wide range of daily activities (da Silva Camassuti et al., 2015; Rawes et al., 1996). The devices have two endblocks with an intervening strain gauge, the ends being placed proximally and distally to a joint axis, as shown in Figure 13. The gauge responds to mechanical deformation. The tensile or compressive forces of joint motion changes electrical resistance in the gauge, measuring the relative angles between the two endblocks (Singh et al., 2012). The devices are able to measure a wide range of movement parameters including joint angles, velocity, duration, repetitions, and smoothness.

Figure 13

DataLITE wireless electrogoniometer



Note. The image shows systems for the elbow and wrist. Retrieved from

http://www.biometricsltd.com/wireless-sensors.htm

8.6.1 Validation

Electrogoniometers have been compared for accuracy of wrist motion against manual goniometry, fluoroscopy, 3D motion capture, cineradiography, and video or photographic analysis and are generally reported as being reliable and accurate (da Silva Camassuti et al., 2015; Hillstrom et al., 2014; McHugh et al., 2020; McKinnon et al., 2020; Ojima et al., 1991; Rawes et al., 1996; Soo-Young & Jin-Yong, 2012). With respect to intra-rater reliability of Biometrics electrogoniometers, ICC values have been reported as 0.94 (0.95-0.99) for wrist flexion/extension and 0.96 (0.92-0.98) for radial/ulnar deviation (Singh et al., 2012). ICC values for inter-rater reliability are slightly lower at 0.89 – 0.91 for flexion/extension and 0.87 – 0.90 for radial/ulnar deviation (Singh et al., 2012). Reliability of manual goniometry is reported as having ICC values of 0.80 – 0.84 for intra- and inter-rater reliability of wrist extension measurement (LaStayo & Wheeler, 1994) suggesting higher reliability of electrogoniometry. For study IV testing was done during a single session with the devices applied only once so test-retest and inter-rater reliability were less relevant for that study.

In an early study, Biometrics electrogoniometers were concluded to be highly accurate (Rawes et al., 1996). In that study mean ranges for wrist flexion, extension, ulnar and radial deviation were reported as 78°, 67°, 40°, and 26° (SD 3°) respectively (Rawes et al., 1996), angles consistent with those of healthy people (Kim et al., 2014; Ryu et al., 1991). A more recent small study showed a mean square error of ±3° for measurement of wrist flexion/extension and radial and ulnar deviation (Shiratsu & Coury, 2003). When compared with 3D motion analysis electrogoniometers showed mean differences of ±7° for wrist flexion/extension (McHugh et al., 2020). Compared with fluoroscopy the mean absolute difference was 5° (SD 4°), across all wrist movements between the two systems (Hillstrom et al., 2014). Comparison between a manual goniometer and an electrogoniometer (MIOTEC, Brazil), found ICC values of 0.87, 95% CI [0.78,0.94] for wrist extension and 0.87 [0.77,0.93] for ulnar deviation (da Silva Camassuti et al., 2015). Agreement between video analysis and electrogoniometry was lower in another small study by McKinnon et al. (2020) who compared Biometrics electrogoniometers with video analysis in a small study. Agreement between the two systems was 57%, (kappa =0.49) for flexion-extension and 68%,(0.30), for radial-ulnar deviation. In a small study that compared electrogoniometry with motion capture, Bland-Altman analysis was used to report on accuracy of the two systems. Accuracy was higher for radial/ulnar deviation (mean difference of -0.8°, limits of agreement -4.1° to 2.5°) than for flexion/extension (7.2°, limits of agreement -0.9° to 15.2°) (McHugh et al., 2020). Flexion/extension had a negative bias suggesting an overestimation of movement and for radial/ulnar deviation there was a positive bias suggesting an underestimation. Overall, it is considered that electrogoniometry is a reliable and valid tool for measurement of wrist motion and the devices are widely used for field-based research where motion capture is not feasible (Singh et al., 2014).

Accuracy of torsiometers for measurement of forearm rotation is generally considered to be lower than for electrogoniometers with error rates above 7° having been reported (Latz et al., 2019; Shiratsu & Coury, 2003). In the small study that compared electrogoniometry with video analysis, lower accuracy for the torsiometers was reported in measuring forearm rotation, 53% (kappa =0.1), than for wrist motion, 57%, (kappa =0.4) for flexion-extension and 68%,(0.30) for radial-ulnar deviation (McKinnon et al., 2020). The lower accuracy of torsiometers is a consideration for study IV but can be mitigated by a single application of the devices, and a crossover design that ensures consistency of measurements within-participants.

It is commonly reported that wrist measurement accuracy is affected by complex motions of the forearm (McKinnon et al., 2020). Known as crosstalk, this problem occurs when there is interference of signals between two planes of motion such as occurs when the wrist is flexed and extended in differing positions of forearm rotation (Foltran et al., 2013; McKinnon et al., 2020). Newer models appear to have rectified this problem (Hughes & Babski-Reeves, 2003) and more recent literature suggests crosstalk errors as being relatively insignificant and mathematical correction not recommended (Foltran et al., 2013; Hansson et al., 2004). It is recommended that if varying positions of forearm rotation are expected during measurement then the sensors should be zeroed in the mid pronation/supination position (Johnson et al., 2002).

8.6.2 Advantages and limitations

Electrogoniometers are similar to accelerometers, in that they can be worn in real-world environments to capture motion during daily activities. The devices are not water-proof, but are otherwise unaffected by heat or electrical interference making it suitable for a range of environments (da Silva Camassuti et al., 2015). It is possible to record data over long periods of time (Foltran et al., 2013). Electrogoniometers have been used for measuring wrist motion following surgery (Singh et al., 2017; Singh et al., 2014), and in rheumatoid arthritis populations (Yayama et al., 2007), demonstrating acceptability of the device in orthopaedic populations.

A distinct advantage of electrogoniometers for study IV was the commercial availability of the devices along with analytic software. The devices and software are costly, but this may be offset by the ready availability of the technology and the lack of development work that would go with accelerometers or wearable gloves. One disadvantage is the inability of the devices to capture visual images of movement requiring concurrent videography during evaluation. The devices have not been used in a postoperative distal radius fracture population so acceptability of applying and wearing the devices is unknown.

8.7 Comparison of three technologies

Table 14 compares the properties, benefits, and limitations of three wearable devices, accelerometers, electrogoniometers, and wearable gloves. Technical data were obtained from manufacturer's websites (Biometrics Ltd, 2020; IMeasureU, 2018; StretchSense).

Table 14

Comparison of three wearable technologies for measuring wrist motion during daily activities

	IMeasureU Blue Thunder accelerometer	Biometric DataLite Wireless Electrogoniometer	StretchSense gloves
Validation for wrist measurement	Partly	Yes	No
Previously used in rehabilitation research	Yes	Yes	No
Advantages	Small, low profile devices Good for monitoring of overall upper limb activity levels	Commercially available with associated analytic software Validated, clinically tested product Light, low profile, suitable for home-based research	Sensors can be placed wherever desired to measure any movement Likely to be highly accurate Light, low profile
Limitations	Limited analysis software Technically challenging for measurement of joint angles	Expensive devices and software Less accurate than 3D motion capture	May inhibit dexterity and sensation May not be tolerated by postoperative population
Technology/sensors used	IMU containing an accelerometer, gyroscope, and a magnetometer	Strain gauge mounted between two endblocks	Capacitive elastomer sensors embedded in gloves
Simultaneous measurement of wrist and forearm motion	Yes, if two-three devices would be required	Yes, with two devices: an electrogoniometer and torsiometer	In principle yes: would require development of a custom glove
Sampling rate	9-axis data logging at 500Hz 3-axis accelerometer data logging at 1000Hz	Selectable sampling rates of 1000, 500, 200, 100 or 50 samples per second on the digital inputs	5 channel - 1000Hz 10 channel - 500Hz

	IMeasureU Blue Thunder accelerometer	Biometric DataLite Wireless Electrogoniometer	StretchSense gloves
Measurement accuracy, drift, cross-talk, hysteresis	Accurate, precise No data on drift or hysteresis	± 2º measured over a range of ± 90º Temperature zero drift - 0.15 degrees angle/ºC Reported issues with crosstalk	Precise, movement and position data are captured down to fractions of a mm
Environmental limitations		Operating temperature range - +10ºC to +40ºC	Operating range 10° to 30°
Battery life	4-6 hours Bluetooth or on-board SD sampling time 2-6 hours	>12 hours	
Charging	Fast-charge via micro USB in 1.5 hours	Rechargeable Li-lon Polymer Battery	Rechargeable Lipo battery
Data storage	On-board storage 32 hours Logged data download via micro USB cable	Data downloaded in real-time to PC	Real-time transfer of data to a mobile device motion capture application
Analysis software	Can be integrated with Vicon Nexus software iOS data acquisition app available – software free for uploading raw data No existing algorithms for wrist motion analysis	Biometrics Ltd DataLITE analysis software with video synchronization, configured to give a wide range of joint motion metrics	Not available
Technical support	For development of algorithms or analysis software - none	UK based company	NZ based company

	IMeasureU Blue Thunder accelerometer	Biometric DataLite Wireless Electrogoniometer	StretchSense gloves
Wearability	Attached to skin with double-sided tape or worn via a strap	Medical grade double sided adhesive tape	Wearable glove. May be difficult to put on due to firm-fit
Interference with motion	Minimal interference with motion Would not fit under a wrist orthosis	Minimal interference, no volar hand sensors Can be worn under clothing Very flexible May not fit under a wrist orthosis	Unknown
Warranty		2-years	
Cost	$2,000-$3,000 per unit	NZD $9,683.30 for 1x wrist goniometer, 1x torsiometer and DataLITE Analysis Software	Unknown

8.8 Summary

The technologies of motion capture, accelerometry, electrogoniometry and wearable stretch sensors have been presented and compared. Motion capture systems are considered to be the gold standard of dynamic joint motion measurement but are limited to laboratory settings and short time-periods of recording. For study IV my preference was to conduct the study in participants homes, and motion capture was not suitable for real-world applications. Field based-motion capture was not sufficiently developed at the time of study development so was similarly unsuitable for study IV. Wrist worn accelerometers were investigated due to their wide availability and ease of use in real-world studies. Technical challenges in accuracy of joint angle measurement were the primary reason accelerometry was not investigated further. Wearable stretch sensors embedded in gloves are a developing technology potentially well-suited to this this project. However, due to the extensive development work that would have been required they were not deemed suitable for this project.

Electrogoniometers were selected for this study as they met the widest range of requirements. They are well-validated for wrist movement, have been used extensively in rehabilitation studies and there were commercially available devices and analysis software. While there were some notable limitations including reported issues with crosstalk and the need for simultaneous videography, these challenges were considered surmountable, and the technology was deemed the most suited to measurement of wrist movement during daily activities.

Chapter 9 Study IV: A motion analysis study

9.1 Chapter overview

This chapter presents the submitted manuscript of a quantitative study. The manuscript was submitted to the Journal of Hand Therapy and is currently under review.

The title of the manuscript is: An evaluation of wrist and forearm movement during purposeful activities and range of movement exercises after surgical repair of distal radius fractures: A randomised crossover study. The authors are, Collis, J. M., Mayland, E. C., Wright-St Clair, V., Rashid, U., Kayes, N., & Signal, N.

Study IV addresses RQ4: Does performance of daily activities result in greater quantity of motion than active range of motion exercises following surgical treatment of distal radius fracture?

The manuscript is included here with citations, figures and tables formatted consistent with the thesis. A summary of the results was sent to participants at the completion of the study and is included in Appendix Z.

9.2 Manuscript study IV

9.2.1 Abstract

Purpose

Following surgical repair of distal radius fractures, range of movement (ROM) exercises are the primary approach for restoring movement during early rehabilitation. Specified purposeful activities can also be used, but the movement produced by activities is not well-understood. The study aimed to evaluate and compare movement during purposeful activity and ROM exercises.

Methods

Thirty-five adults with a surgically repaired distal radius facture undertook two 10-minutes interventions: purposeful activity (PA) and active ROM exercises (AE), separated by a 60-minute washout, in random order. Data collection occurred during a single session on the same day. Electrogoniometry was used to measure time-accumulated position (TAP), a global metric of movement range

and amount, maximum active end range, movement repetitions, excursions >75% of available ROM and active time. Data were analysed using linear mixed and generalised linear mixed regression models.

Results

Purposeful activities selected were predominantly household or food preparation. TAP was significantly higher during AE than PA: -1878 [-2388, -1367], p=<0.001, for wrist extension/flexion. PA produced significantly greater movement repetitions for wrist extension/flexion and deviation, excursions beyond 75% of available ROM, and active time, than AE. During PA the wrist was extending/flexing a mean of 97% [92, 101], of the time, compared with 43% [40, 47], during AE. There were no significant differences in maximum end range for wrist extension between PA, 33.7° [29.8, 37.5] and AE, 34.5° [30.7, 38.4], or for ulnar deviation.

Conclusions

ROM exercises produced higher volumes of sustained joint position than purposeful activity but activities, selected for importance and challenge, produced significantly higher volumes of continuous, repetitious motion in equivalent ranges of movement as exercise repetitions. The study challenges therapists to consider the rehabilitative potential of movement produced by activity for restoring movement and function in the early postoperative weeks.

9.3 Introduction

Following a distal radius fracture, surgical repair is commonly performed to restore stability and anatomical alignment to the bone (MacFarlane et al., 2015; Quadlbauer et al., 2020). During the early weeks of recovery many people experience wrist stiffness, sensorimotor impairments, and functional loss, and these sequelae can persist for months after surgery (Karagiannopoulos et al., 2013; Kong et al., 2020; MacFarlane et al., 2015; Wollstein et al., 2018). To restore movement and functional use of the affected wrist, mobilisation is generally recommended within two weeks of surgery (Collis et al., 2020a; Gutiérrez-Espinoza et al., 2021). The predominant component of early mobilisation regimes is active range of movement (ROM) exercises (Bruder et al., 2013; Ziebart et al., 2019). Performing light, non-forceful daily activities is another way to elicit movement and may also be used to remediate wrist stiffness in the first six postoperative weeks (Collis et al., 2020a). Despite daily activities being suggested as an early postoperative rehabilitative strategy (Kooner & Grewal, 2021; Quadlbauer et al., 2020), specified use of daily activities is frequently overlooked and poorly described (Collis et al., 2020a; Hays & Rozental, 2013; Michlovitz et al., 2004).

The therapeutic use of daily activities may have actions distinct to ROM exercises and may have greater therapeutic potential than recognised. Our qualitative research elucidated that people with a surgically repaired distal radius fracture highly value occupation for restoring movement and function, and for positively influencing wellbeing (Collis et al., 2021). Purposeful activity has been shown to produce greater quantity of movement than non-purposeful movement in healthy, and neurological populations (Collis et al., 2020b; Hétu & Mercier, 2012; Lin et al., 1997). One early study in people with hand injury suggested that purposeful activity resulted in more movement repetitions than non-purposeful activity (King, 1993). Taken together, the body of research suggests that purposeful activities may be an untapped source of therapeutic movement in people with surgically repaired distal radial fracture.

One of the barriers to utilising purposeful activity as therapy may be that movement during activity is poorly understood. As studies have reported that activities of daily living do not necessarily utilise full ROM at a particular joint (Gates et al., 2016; Palmer et al., 1985; Ryu et al., 1991), it is often assumed that activities are ineffective at restoring active end ROM after injury (Gracia-Ibáñez et al., 2017). Studies that determined wrist ROM requirements for functional activities were conducted in healthy people, using pre-determined activities. It may be that ROM differs when activities are selected and performed with the goal of encouraging joint movement after wrist injury. We do not know if activity produces movement to the limits of the available active range or whether activities are performed in a smaller range due to fear, pain, or muscle weakness. Evaluating wrist movement during purposeful activities, and comparing with active ROM exercises, may give insights that can inform the clinical use of purposeful activities.

A study was therefore designed to evaluate wrist movement during purposeful activity compared with a set of active ROM exercises. The aim of this study was to determine whether similar or better movement quantity is achieved during purposeful activities compared with range of movement exercises of the same duration in individuals with surgical treatment of distal radius fracture.

9.4 Methods

9.4.1 Study Design and Setting

We conducted an exploratory biomechanical study utilising a randomised crossover design. The study design and protocol were informed by the CONSORT extension for crossover trials (Dwan et al., 2019). Participants took part in two interventions: purposeful activity (PA) and active ROM exercises (AE), separated by a washout period of 60-minutes, in a random order. Purposeful activity was defined as an action or set of tasks that has meaning and perceived utility to the individual. When grouped together, purposeful activities make up broad categories of occupation including work, leisure, social participation, and activities of daily living (American Occupational Therapy Association, 2020; Polatajko et al., 2004). Movement parameters were measured during each intervention including accumulated joint position over time, maximum active end range, numbers of repetitions, excursions beyond 75% of available ROM and percentage of active movement time. Data were collected in a single session on the same day in the person's own home.

The trial was registered with the Australian New Zealand Clinical Trials Registry, number 379899 on the 29/06/2020. Ethical approval was received from the New Zealand Health and Disability Ethics Committee, number 20/NTA/28, on the 18th May 2020 (Appendix S) and localities approval from Counties Manukau Health on the 18th June 202 (Appendix T).

9.4.2 Participants

Adults with surgical repair of a distal radius fracture in Auckland, New Zealand were invited to participate. Eligibility criteria are detailed in Table 15. A sample size calculation was conducted based on a related but different outcome measure of movement repetitions (King, 1993), using a repeat-measures matched paired t-test, as there were no known studies that used the same primary outcome. It was determined that a minimum of 32 participants would be needed at a significance level of 0.05, Cohen's d effect size of 0.66 and 95% power.

Table 15

Eligibility criteria

Inclusion
Aged over 18 years
Surgical repair of a distal radius fracture
Less than four weeks postoperative
Stable fixation, deemed by surgeon to be suitable for mobilisation
Conversational English
Exclusion
Any condition or injury that significantly affects normal use of the affected limb e.g., severe arthritis, stroke
Concomitant fracture of another bone (except ulna styloid fracture)
Concomitant surgical repair of tendon, muscle, or nerve

9.4.3 Interventions

The interventions were self-selected purposeful activity (PA) and standardized active ROM exercises (AE) and are detailed in Table 16. Each intervention session was 10-minutes, estimated as the time it would take to complete a set of range of motion exercises or perform a purposeful activity. Purposeful activities were selected prior to, or on the day of testing, by participants, based on the criteria in Table 16. A list of suggested activities was supplied at visit one (supplementary file 1) (Appendix U), developed from studies that identified activities performed by patients during the first six postoperative weeks (Collis et al., 2021; Collis et al., 2020a). Self-selection was considered essential to ensure the activities had meaning and value to the participants (Collis et al., 2020b).

Table 16

Interventions

Purposeful activity (PA)	Active exercise (AE)
Light, non-forceful, part of rehabilitation at the time of data collection	Part of usual rehabilitation
Encouraged and challenged wrist movement	Standard postoperative forearm, wrist, and hand active ROM exercises [i]
Required repeated wrist and forearm movement	10 repetitions of each movement in the same order
Important or enjoyed	Repetitions held at comfortable active end-range for 3 seconds
Take at least 10-minutes to perform	
Activities could be combined e.g., emptying the dishwasher, and preparing vegetables	If completed before 10-minutes exercises were repeated

[i] Detailed in supplementary file 2 (Appendix V).

9.4.4 Study procedures

Potential participants were invited to participate by hand therapists independent to the study, at the person's initial hand therapy visit (see study flyer in Appendix W). Interested people were contacted by the researcher (JC) and a first visit arranged to explain the study and obtain informed consent (Appendix X). Data collection was scheduled to occur at visit two, between weeks four and eight following surgery. The randomisation schedule was pre-generated via a computerised program (Labes, 2019), and was balanced across periods (interventions one and two) and sequences (PA:AE and AE:PA). Data were collected by the primary author (JC), who was not blinded to the interventions. Participants were blinded to the study hypotheses. On arrival at visit two, the researcher (JC) checked that the self-selected purposeful activities met the criteria as detailed in Table 16, informed the participant of the randomisation order, and set up the recording equipment. Baseline ROM recordings were taken of wrist and forearm movement. The clinical characteristics of pain and kinesiophobia were recorded at baseline using an 11-point rating scale for pain (NRS-11) (Hawker et al., 2011), and a short form of the Tampa Scale of Kinesiophobia (TSK-FOIE) for kinesiophobia (George et al., 2012). Instructions were read, and the first intervention was performed. Prior to both interventions participants were instructed to move the wrist as much as possible, within comfort levels, and that a rest could be taken if needed. At the completion of the first 10-minute intervention a wrist orthosis was applied to immobilise the wrist and the washout began. The washout period was 60-minutes, which was considered long enough to avoid carryover effects. After 60-minutes the orthosis was removed. Pain was re-scored, the instructions re-read, and the second intervention performed. The questions relating to meaning, enjoyment and challenge were scored immediately after each intervention. No coaching or prompting was given during the interventions.

9.4.5 Outcomes

Movement parameters were selected to quantify the range, and amount of movement. The parameters provide clinically meaningful data, and are reported in relation to wrist extension, ulnar deviation, and supination, as loss of these movements are associated with the greatest functional limitations (Lucado et al., 2008; Wilcke et al., 2007; Yang et al., 2018). The primary outcome was time-accumulated position (TAP), a global metric of movement range and amount, reflecting cumulative joint position away from zero over time. Secondary outcomes for ROM were maximum active end range and number of excursions >75% of available active end range, and for amount of movement were number of repetitions and active time. The outcomes are detailed in Table 17. Participants were asked to rate the importance, enjoyment, and challenge of the interventions on a 5-point ordinal scale from 1 (not at all), to 5 (very).

Table 17

Movement parameters

Outcome	Movements	Acronym	Units	What the outcome measures	Method of calculation
Time-accumulation of position	Radial/ulnar deviation Extension/flexion Pronation/supination	TAP Dev TAP EF TAP Rot	°-s (degrees-seconds)	Area under the curve. A measure of accumulated joint position away from zero over time	Biometrics DataLITE V10.28, calculated as area under the curve
Maximum active end ROM	Ulnar deviation Wrist extension Supination	MaxER UD MaxER WE MaxER Sup	Degrees	The greatest degree of active joint ROM achieved during 10-minutes of recording. A measure of amplitude.	
Excursions >75% of active ROM	Ulnar deviation Wrist extension Supination	E>75% UD E>75% WE E>75% Sup	Counts	Number of times the joint moved beyond 75% of the available arc of active movement	Biometrics DataLITE V10.28, 75% of available active end ROM was calculated from the baseline ROM measures
Movement repetitions	Radial/ulnar deviation Extension/flexion Pronation/supination	MR Dev MR EF MR Rot	Counts	A change in direction twice in succession of greater than 9° (5% of the 180° scale)	Biometrics DataLITE V10.28, as a number count for repetitions
Active time	Radial/ulnar deviation Extension/flexion Pronation/supination	AT Dev AT EF AT Rot	Percentage	The ratio of time between wrist movement and inactivity	Activity = velocity >5°/s; inactivity = velocity remains ≤5°/s for half a second

9.4.6 Instrumentation

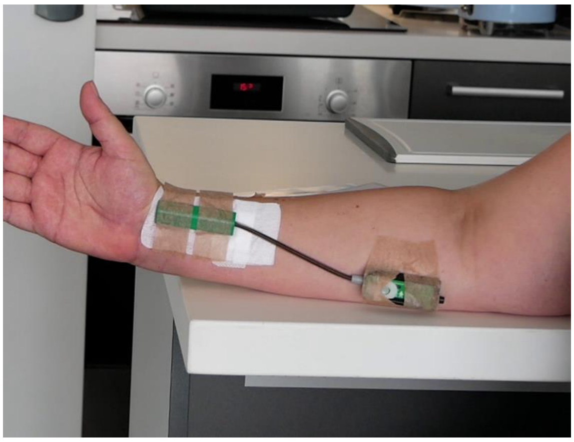
A Biometrics twin-axis goniometer W65 was used to measure wrist movement and a Z110 or Z180 torsiometer for forearm movement. The validity of electrogoniometers has been determined (Hillstrom et al., 2014; Ojima et al., 1991), and they are widely used in wrist post-surgical research (Singh et al., 2017; Singh et al., 2014). Compared with 3D motion capture or fluoroscopy error rates of 5-7° have been reported.(Hillstrom et al., 2014; McHugh et al., 2020). Error rates above 7° have been reported for torsiometers (Latz et al., 2019; Shiratsu & Coury, 2003). Biometrics DataLITE analysis software version 11 was used to record outcomes, excepting percentage of active time where a custom code was written. Participants were filmed during the interventions for the purpose of time-stamping movements. The electrogoniometer was positioned with the arm abducted and in a relaxed posture, the distal block was affixed to the third metacarpal using double sided adhesive. The wrist was then flexed and the proximal block affixed to the forearm in the midline between the radius and ulna (Biometrics Ltd, 2020; Heilskov-Hansen et al., 2014). Tape was used to further prevent movement of the devices (Figure 14). The torsiometer was attached with the elbow flexed to 90°, in neutral rotation. The distal block was positioned proximal to the wrist joint, along the flexor carpi radialis tendon. The proximal end was attached proximal to the medial epicondyle in line with the ulna (Figure 15), (Adewuyi et al., 2017; Biometrics Ltd, 2020; Coury et al., 2000). A manual goniometer was used to establish the zero position of neutral rotation, wrist deviation and extension/flexion.

Figure 14

Electrogoniometer positioned on the dorsum of the hand

Figure 15

Torsiometer positioned on the volar forearm



9.4.7 Statistical methods

An independent research assistant screened the data for abnormal values, cleaned, and processed the data. A blinded statistician (UR) conducted the analysis. Linear mixed and generalised linear mixed regressions separately regressed each outcome by movement type, condition, and the interaction of movement type with condition. An unstructured participant-wise random-intercept for each movement type was included. Carry-over effects were tested for and dropped if not statistically significant. The means for the outcomes across conditions under different movement types and differences across conditions are reported with their 95% confidence intervals and test statistics for the null hypothesis that the means across conditions are equal. The normality and uniform-variance assumptions for the linear mixed models were evaluated, and data was modelled with Gamma distribution if needed. Statistical significance level was set at 0.05. The analysis was conducted in R version 4.1.1 using packages: nlme, lme4, r2glmm, emmeans. Pain and TSK-FOIE scores were treated as covariates in the analysis.

9.4.8 Results

Between November 2020 and June 2021, 35 people were randomised to sequence PA:AE or AE:PA (Figure 16). Participant characteristics are detailed in Table 18. Participants selected a broad range of purposeful activities to perform (Table 19). Over half of the participants performed one activity 21(60%), while the remaining 14(40%) chose 2 or 3 activities. Supplementary file 3 presents a video montage of the types of activities performed by participants.

Supplementary file 3 Purposeful Activities montage.mp4

Figure 16

Consort 2010 study flow diagram

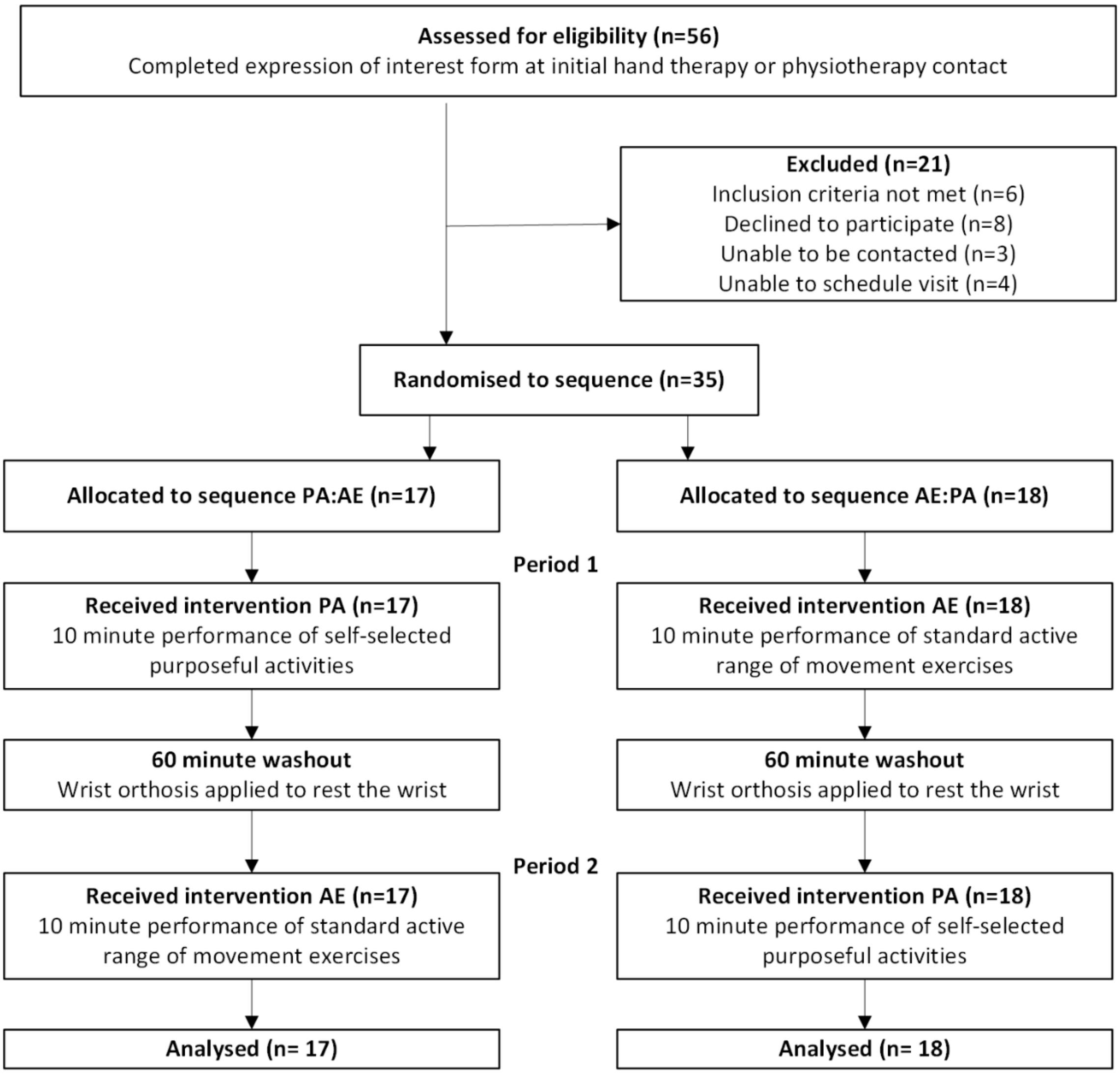


Table 18

Participant characteristics (n=35)

Variable		N (%)	Mean ± SD	Range
Age			51 (16)	19-76
Pain at baseline[1]			1 (1)	0-4
TSK – FOIE[2]			7 (3)	3-12
Days injury to surgery			10 (8)	2-38
Days surgery to mobilisation			15 (5)	8-27
Days surgery to data collection			36 (9)	10-55
Sex	Female	27 (77)		
	Male	8 (23)		
Ethnicity	NZ European	25 (71)		
	NZ Māori	3 (9)		
	Other	7 (20)		
Side of injury	Left	20 (57)		
	Right	15 (43)		
Dominant side injured		15 (43)		
Comminuted fracture		34 (97)		
Intra-articular fracture		31 (89)		
Surgical procedure	Volar plate	35 (100)		
Additional fixation	Dorsal plate	2 (6)		

[1]11-point numeric rating scale. 0=no pain, 10=worst possible pain

[2]Tampa Scale of Kinesiophobia – Fear of Injury Early. Score range is 3 (low kinesiophobia) to 12 (high kinesiophobia)

Table 19

Self-selected activities performed by participants

Occupation[1]	Activity[1]	N=
Instrumental Activities of Daily Living (IADLs)		
Household management	Folding laundry	13
	Hanging out clothing on washing line or clothes airer	3
	Ironing	3
	Washing windows	1
	Tidying and sorting drawer contents	1
	Making the bed	1
	Cleaning kitchen benches	1
	Unloading or loading the dishwasher	4
	Washing, drying, and putting away dishes	5
	Putting away groceries, folding paper grocery bags	1
Meal preparation	Making a salad, preparing vegetables, making a salad sandwich	7
	Making a cup of tea	1
Pet care	Grooming small dog	1
Gardening	Watering plants	1
	Weeding or pruning	2
	Pulling out rhubarb	1
	Planting herbs	1
Activities of Daily Living (ADLs)		
Dressing, Personal hygiene & grooming	Putting on shoes & socks, putting on a shirt, doing up hair, putting in earrings, applying face cream	3
Work		
Job performance	File management, computer use	1
Leisure		
Recreation	Playing the ukulele	1
	Drawing	1
	Hand sewing – repairing child's bag	1

1Occupations and activities are categorised according to the OTPF-4.(American Occupational Therapy Association, 2020)

Statistically significant differences between purposeful activity and active ROM exercises were observed in the majority of movement outcomes. There was no carryover effect detected in the data for any outcome. There were no interactions between the covariates of pain, kinesiophobia, injury or surgery characteristics, time from surgery to mobilisation or evaluation, and movement outcomes. Outcomes from the model analysis are reported in Table 20. Means and confidence intervals for PA and AE are detailed in Table 21 and illustrated in Figure 17,Figure 18, Figure 19, Figure 20, and Figure 21. Box and scatter graphs visualising the raw data are provided in supplementary file 4 (Appendix Y).

Time-accumulation of position

For the primary outcome, active exercise produced significantly higher time accumulated joint position than purposeful activity regardless of movement type. For wrist flexion/extension the mean difference was -1878 deg-sec, 95% CI, [-1367, -7.260]. To illustrate, in 10-minutes a person who performed ROM exercises, produced 43% more sustained time-accumulated extension-flexion than during purposeful activity.

For the secondary outcomes, purposeful activity predominantly achieved greater or similar quantity of movement than active exercises (Table 20 and Table 21).

Maximum active end ROM

Maximum active end range was not statistically different between purposeful activity and ROM exercise. Mean wrist extension during PA was 33.7° [29.8, 37.5], and 34.5° [30.7, 38.4], during AE. Purposeful activity produced lower maximum end range for supination 34.3° [29.5, 39.1], compared with active exercise, 40.0° [35.2, 44.8]. An excerpt of a data trace illustrating maximum end range is provided in Figure 22.

Excursions >75% of active ROM

Purposeful activities produced significantly more excursions beyond 75% of available ROM for ulnar deviation and wrist extension. For wrist extension the mean difference was 54, 95% CI [24, 85], $p<0.001$. For supination the opposite was seen where exercise resulted in a greater number of excursions than purposeful activities, -12, 95% CI [-18, -6], $p<0.001$.

Movement repetitions

Purposeful activities resulted in significantly more movement repetitions than ROM exercises for forearm rotation and wrist extension-flexion. For extension-flexion there was a mean of 119.6, 95% CI [100.9, 138.4] repetitions during purposeful activity as opposed to 51.7, 95% CI [42.8, 60.6] for active exercise. There were no significant differences between the interventions for wrist deviation.

Active time

For the percentage of time the wrist was moving, a significant difference was seen in favour of purposeful activities for all movement types, $p<0.001$. For the extension/flexion arc of motion the mean difference was 53, 95% CI [50, 57]. During purposeful activity the wrist was extending/flexing a mean of 97%, [92, 101] of the time, compared with 43%, [40, 47], during active exercises.

Table 20

Model analysis of movement outcomes, PA versus AE

Outcome	Movement	Difference	SE	DF	95% CI Lower	95% CI Upper	T or Z-value	P-value
TAP	Rot	-2943	445	170	-3821	-2065	-6.616	<0.001*
	Dev	-1446	183	170	-1807	-1085	-7.914	<0.001*
	EF	-1878	259	170	-2388	-1367	-7.260	<0.001*
MaxER	Sup	-5.7	2.1	170	-9.8	-1.6	-2.756	0.006*
	UD	0.3	0.8	170	-1.3	2.0	0.422	0.673
	WE	-0.9	0.9	170	-2.7	0.9	-0.951	0.343
E>75%	Sup	-12	3		-18	-6	-3.703	<0.001*
	UD	42	12		19	65	3.566	<0.001**
	WE	54	16		24	85	3.492	<0.001**
MR	Rot	117.5	11.9		94.1	140.9	9.845	<0.001**
	Dev	-0.2	0.8		-1.7	1.3	-0.296	0.767
	EF	67.9	9.6		49.1	86.7	7.074	<0.001**
AT	Rot	52	2		49	56	28.516	<0.001**
	Dev	59	2		56	62	36.115	<0.001**
	EF	53	2		50	57	29.975	<0.001**

*Statistically significant in favour of active exercise

** Statistically significant in favour of purposeful activity

AT: percentage of active movement time; Dev: deviation; E>75%: number of excursions beyond 75% of available active end range; EF: extension flexion; MaxER: maximum active end range of motion; MR: movement repetitions; Rot: rotation; Sup: supination; TAP: time accumulation of position; UD: ulnar deviation; WE: wrist extension

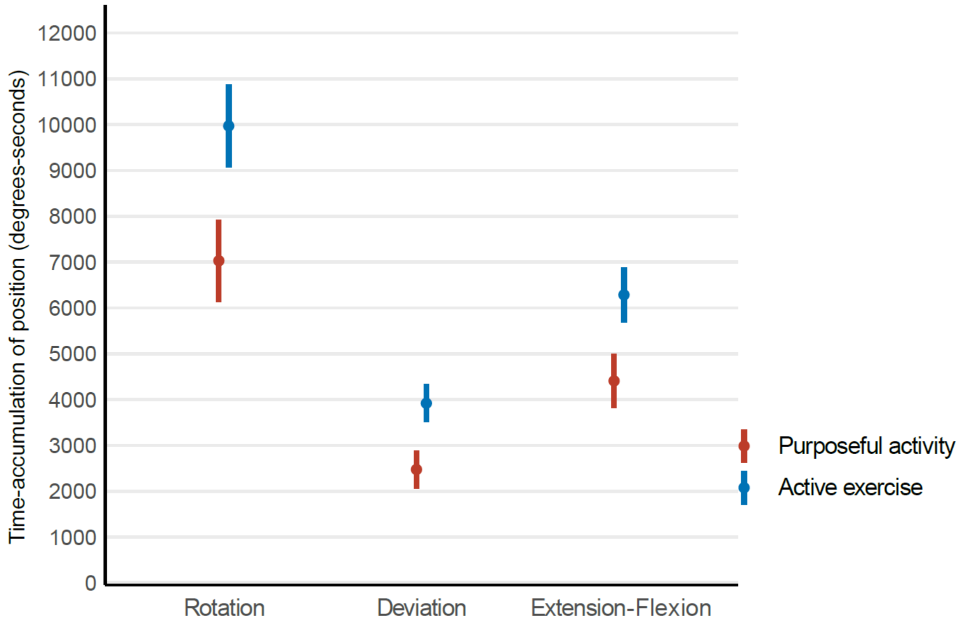
Table 21

Mean values for PA and AE with 95% CIs

Outcome	Condition	Movement	Mean	95% CI Lower	95% CI Upper
TAP	PA	Rot	7027	6131	7923
	AE	Rot	9970	9074	10867
	PA	Dev	2472	2059	2886
	AE	Dev	3918	3504	4332
	PA	EF	4406	3812	5000
	AE	EF	6284	5690	6877
MaxER	PA	Sup	34.3	29.5	39.1
	AE	Sup	40.0	35.2	44.8
	PA	UD	18.1	15.6	20.7
	AE	UD	17.8	15.2	20.3
	PA	WE	33.7	29.8	37.5
	AE	WE	34.5	30.7	38.4
E>75%	PA	Sup	7	5	9
	AE	Sup	19	13	25
	PA	UD	69	47	90
	AE	UD	26	18	35
	PA	WE	89	61	118
	AE	WE	35	24	46
MR	PA	Rot	160.6	136.8	184.3
	AE	Rot	43.0	34.9	51.1
	PA	Dev	31.8	24.7	39.0
	AE	Dev	32.1	24.9	39.3
	PA	EF	119.6	100.9	138.4
	AE	EF	51.7	42.8	60.6
AT	PA	Rot	98	94	100
	AE	Rot	46	42	50
	PA	Dev	91	87	96
	AE	Dev	33	29	36
	PA	EF	97	92	100
	AE	EF	43	40	47

Figure 17

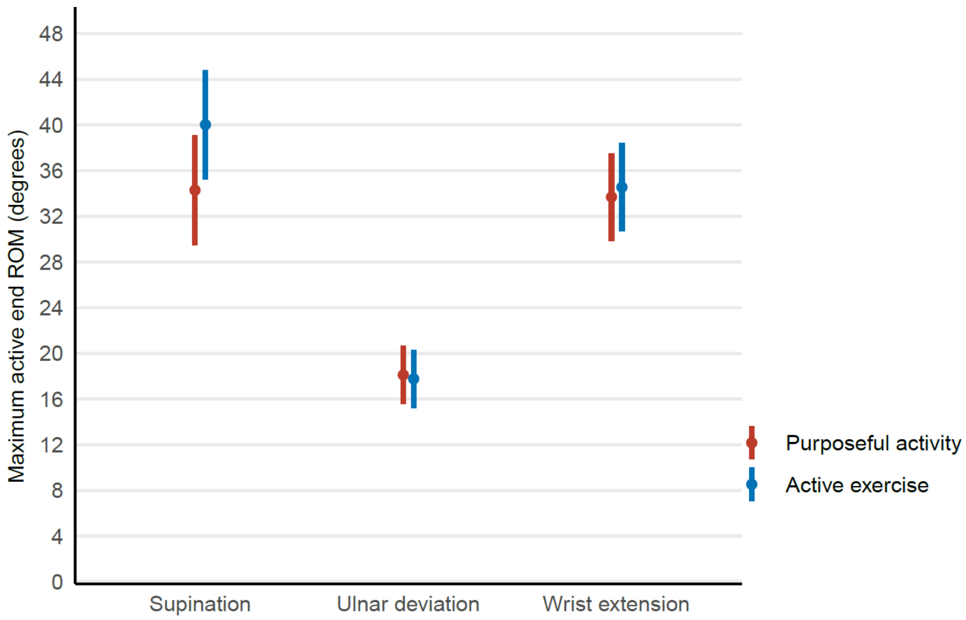
Time-accumulation of joint position for all movement types



Note. *The dots represent the expected degrees-seconds, and bars the 95% confidence intervals*

Figure 18

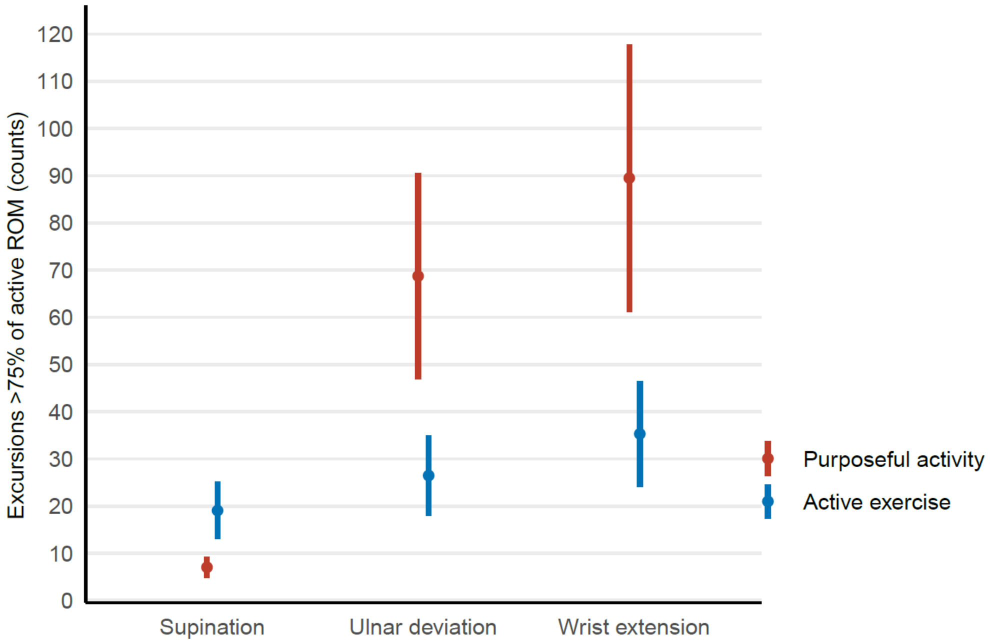
Maximum active end ROM for all movement types



Note. *The dots represent the expected degrees of movement, and bars the 95% confidence intervals*

Figure 19

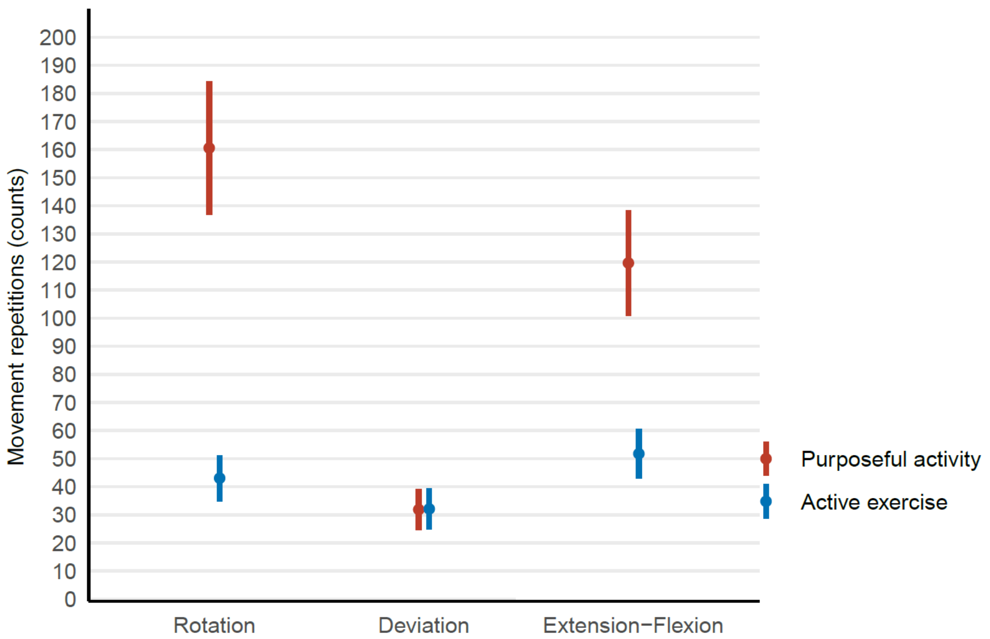
Excursions beyond 75% of active ROM for all movement types



Note. *The dots represent the number of excursions, and bars the 95% confidence intervals*

Figure 20

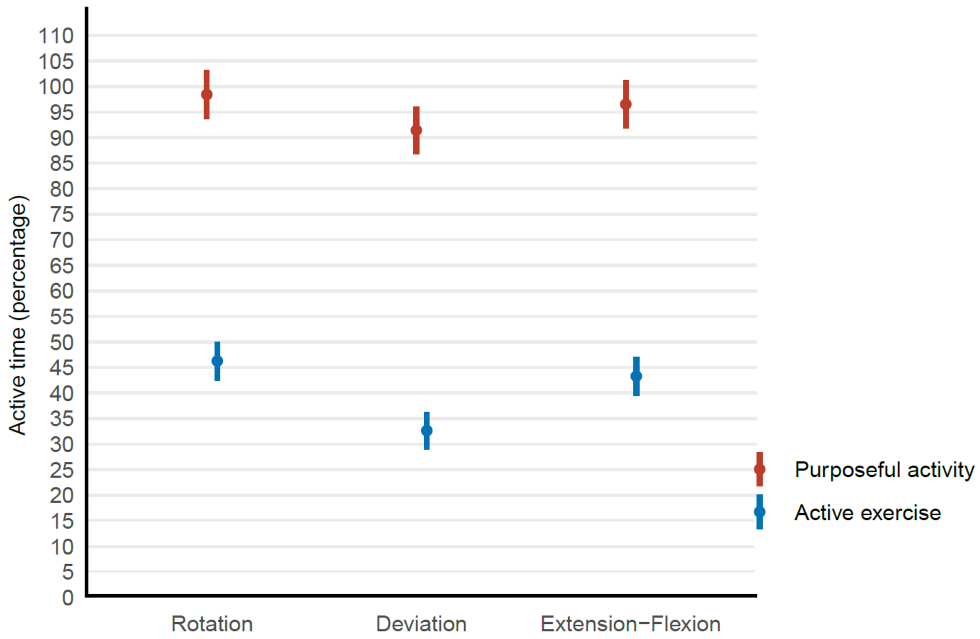
Movement repetitions for all movement types



Note. *The dots represent the expected number of repeitions, and bars the 95% confidence intervals*

Figure 21

Active time for all movement types



Note. *The dots represent the expected percentage, and bars the 95% confidence intervals*

Importance, enjoyment, and challenge

Purposeful activity and exercises were similarly valued for importance and enjoyment (p =0.07 and 0.154 respectively). Participants perceived exercises to be significantly more challenging than performing activities (Table 22).

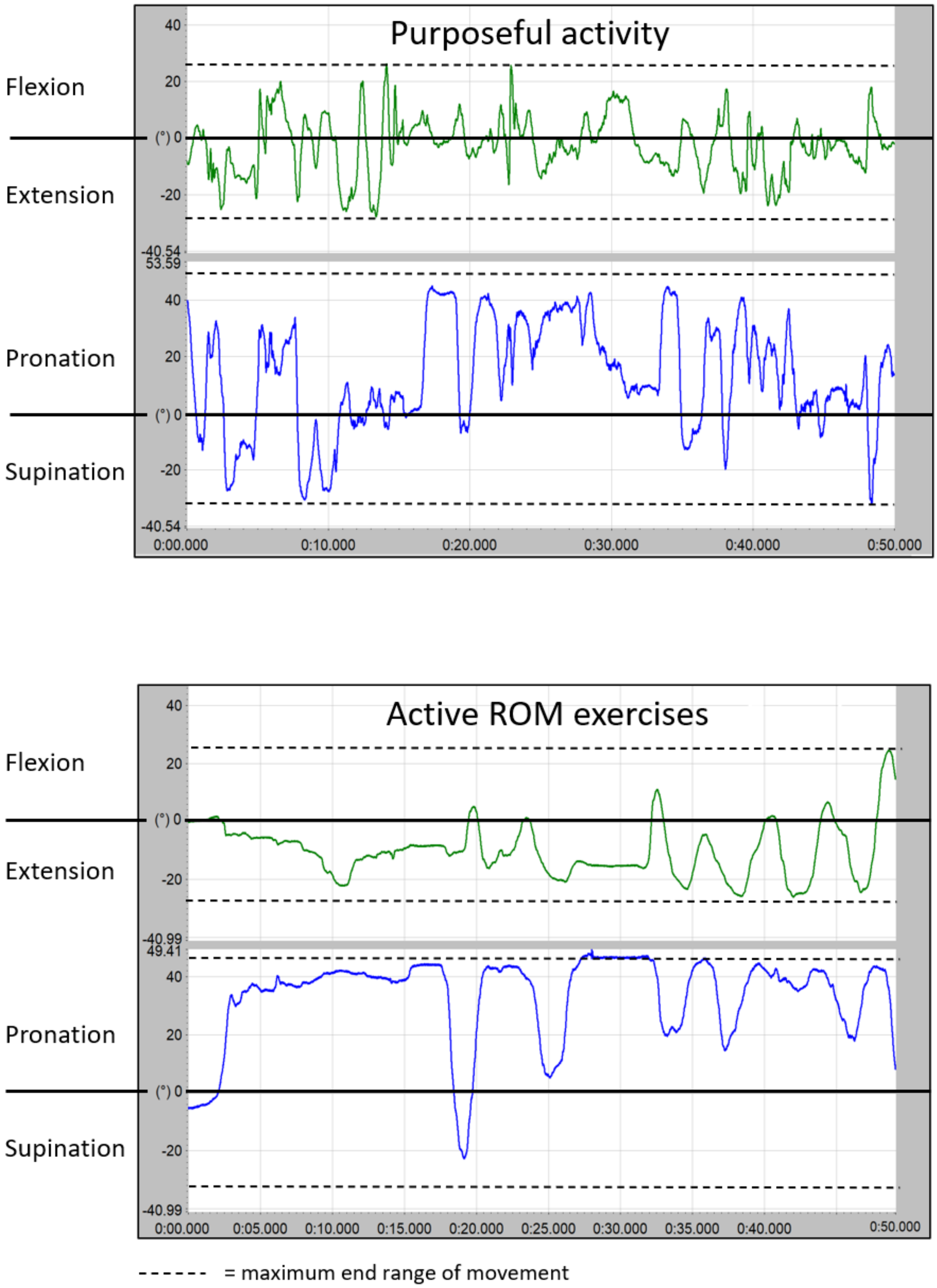
Table 22

Model analysis of perceived importance, enjoyment and challenge, PA versus AE

Outcome	Difference	SE	D.F.	95% CI Lower	95% CI Upper	T-value	P-value
Importance	-0.2	0.1	34	-0.4	0	-1.871	0.07
Enjoyment	0.4	0.3	34	-0.2	1	1.46	0.154
Challenge	-0.5	0.2	34	-0.9	-0.1	-2.359	0.024*

Figure 22

A comparison of maximum end range for purposeful activity and active ROM exercises



Note. *The data are a 50-second excerpt, from the same participant for the same time period*

9.5 Discussion

To our knowledge, this study is the first direct comparison of movement elicited during an equal duration of purposeful activity and exercises in the early weeks following surgical repair of a distal radius fracture. We found that while purposeful activity and ROM exercises both elicited large volumes of wrist and forearm movement, the parameters of that movement were demonstrably different between the interventions. ROM exercises produced significantly greater accumulation of joint position and end range supination than purposeful activity. Purposeful activity produced significantly more movement repetitions, excursions beyond 75% of the available ROM, and a greater proportion of active time. Maximum active wrist extension and ulnar deviation did not differ significantly between the interventions.

Our primary outcome, time-accumulation of position (TAP) encompasses both movement range and amount. The greater accumulation of TAP during ROM exercises reflects that the joint is slowly moved away from zero to a relatively consistent end position and held there for several seconds during each repetition. In contrast, our secondary outcomes of maximum end ROM, excursions >75% of ROM, movement repetitions, and active time, illustrate that during purposeful activity, movement is more continuous and variable, with frequently changing speed, direction, and end position. Given that regenerating tissues are highly responsive to the specifics of mechanical loading (Ng et al., 2017), it is plausible that differences in the characteristics of movement seen during purposeful activity and ROM exercises, may have differential effects on bone and soft tissue regeneration (Ng et al., 2017). Greater understanding of mechanobiological effects of purposeful activity and ROM exercises on healing tissue may inform the type, timing, and intensity of rehabilitation.

Range of movement

An important and surprising finding of our study was the equivalence in wrist ROM produced by both interventions. A common clinical perspective is that purposeful activities are unlikely to restore full ROM after injury because studies in healthy people have demonstrated that activities of daily living do not require full ROM to perform (Gates et al., 2016; Gracia-Ibáñez et al., 2017). Although our mean maximum wrist extension for both interventions was lower than ranges reported for healthy people, ROM was consistent with expected movement 4-8 weeks after surgery (Clementsen et al., 2019; Quadlbauer et al., 2017; Watson, Haines, et al., 2018). A primary goal of early rehabilitation is to increase range of motion without overloading healing tissue (Naughton & Algar, 2021). Our study challenges the reliance on ROM exercises, and suggests that patients may be able to perform either intervention to promote ROM. It is possible that when people are focused and engaged in purposeful activity, they are better able to tolerate slight discomfort associated with end of range movement (Weinstock-Zlotnick & Mehta, 2018). In addition, the significantly higher number of excursions >75% of active ROM, during purposeful activity, may have a greater effect on improving range of motion over time than ROM exercises, particularly when those excursions are accumulated over waking hours.

With respect to ROM for supination, we found that exercises produced higher maximum end range than purposeful activities, albeit with a small magnitude of difference. However, we also noted that some activities, such as the rotating of a tea-towel while drying dishes or holding items in an upturned palm (Figure 23), were particularly effective at promoting supination, suggesting that activities may be selected to promote specific movements.

Figure 23

Activities that promoted supination. A: carrying light household items; B: rotating a tea towel when drying dishes

Amount of movement

Achieving sufficient movement dosage during early rehabilitation is often challenging as patients are often reticent to move the operated limb, may over-use wrist orthoses, or perform fewer exercises than advised (Collis et al., 2021;

Lyngcoln et al., 2005; Quadlbauer et al., 2020). This study demonstrates that purposeful activities produce high doses of wrist and forearm movement. Our modelling indicates that people who perform 10-minutes of purposeful activity achieve 68 more wrist extension-flexions, 118 more forearm rotations and more than double the active time than during 10-minutes of ROM exercises. We suggest that extrapolated over waking hours, the ability of purposeful activity to augment wrist and forearm movement quantity over and above exercise sessions, may be substantial.

High movement dosage following surgical treatment of distal radius fractures is important. In our qualitative study, participants described a direct relationship between the quantity of active movement and recovery of movement and function (Collis et al., 2021). Studies have shown that greater amounts of movement can help resolve oedema, prevent joint adhesions and stiffness (Glasgow et al., 2010; Kong et al., 2020), increase grip strength, and reduce pain (Mitsukane et al., 2015; Shimose et al., 2011). Greater movement dosage has also been shown to promote neural plasticity (Van Vliet & Heneghan, 2006; Wollstein et al., 2018), which may help to resolve sensorimotor impairments such as disrupted motor planning, altered proprioception and sensation, and body perception disturbances, which commonly occur after distal radius fracture (Hall et al., 2016; Imai et al., 2018; Karagiannopoulos et al., 2013; Wollstein et al., 2018).

Purposeful activity as rehabilitation

It is notable that participants rated purposeful activity and exercises as equally important and enjoyable. Our qualitative research illustrates that patients highly value the focus and defined therapy of exercise repetitions for improving movement. Activities are also perceived to improve movement but are additionally valued for their capacity to restore normal body schema, enhance wellbeing and motivation, and promote self-efficacy (Collis et al., 2021; Stern et al., 2021; Watson, Martin, et al., 2018). Therapists should be cognisant of the perceived values and actions of purposeful activities and ROM exercises when designing postoperative rehabilitation with their patients.

The movement characteristics of purposeful activity elucidated in this study may contribute to our mechanistic understanding of the favourable results seen in response to occupation-based interventions (Daud, Yau, Barnett, Judd, et al., 2016; Guzelkucuk et al., 2007; Omar et al., 2012; Weinstock-Zlotnick & Mehta, 2018), and early mobilisation regimes after wrist fracture (Collis et al., 2020a; Ghaddaf et al., 2021; Gutiérrez-Espinoza et al., 2021). The unique characteristics of purposeful activity such as bilaterality, object manipulation, and variable load, speed, and direction of movement (illustrated in Figure 24), may also contribute to the beneficial effects of occupation-based interventions.

Figure 24

Purposeful activity has unique characteristics such as object manipulation, bilaterality, variable load and movement directions.

Clinicians may experience tension with recommending purposeful activities early after surgical repair, for fear of overloading healing tissues (Quadlbauer et al., 2020; Stephens et al., 2020). This can result in inconsistent or confusing advice being given to patients (Collis et al., 2021; Collis et al., 2020a), that can cause patients anxiety, uncertainty, and distress in the early postoperative weeks (Stern et al., 2021; Watson, Martin, et al., 2018). A recent study showed that giving clear information and strategies that promoted engagement in meaningful activities, was empowering, and gave participants a sense of control over their recovery (Stern et al., 2021), highlighting the need for activity-specific education.

While research and expert commentaries confirm the safety of activity performance after surgery for distal radius fracture (Collis et al., 2020a; Gutiérrez-Espinoza et al., 2021; Kooner & Grewal, 2021; Quadlbauer et al., 2020), therapists may still be uncertain about their patient's ability to select activities safely. In our study, participants were asked to choose their own purposeful activities. While some participants required reassurance, all selected activities that were light, encouraged wrist movement, and valued (Table 16). This indicates that when provided with clear guidance, patients are able to competently select activities that are commensurate with stages healing, and furthermore, that challenge movement (Collis et al., 2021). Our participants perceived purposeful activities to be less challenging than exercises, further indicating the ease with which participants can integrate purposeful activities into rehabilitation regimes.

Purposeful activities offer constantly occurring therapeutic movement opportunities that may be underutilised during early rehabilitation. Our study suggests that clinicians may use purposeful activity to augment movement dosage during waking hours and produce ROM that is similar to that achieved during ROM exercises, but in greater quantities. Informed by this study and prior work (Collis et al., 2021), clinicians may guide patients in the types of activities that can be performed with appropriate grading, in the early weeks of rehabilitation.

Strengths, limitations, and future directions

A strength of our study is that we obtained real-world data during the proliferative and early remodelling weeks of bone healing. We did not tightly control the selection or performance of activities as this represents the real choices patients make. Limitations include a power calculation based on an early, low quality study, meaning that optimal sample size was unknown. The lower accuracy of torsiometers may have underestimated supination (Latz et al., 2019). but was mitigated by a single application of the devices, and a crossover design that ensures consistency of measurements within-participants. Lack of researcher blinding could have influenced activity selection or performance. This was mitigated by applying standardised instructions, not giving any prompting, and participant-selection of activities. Future research should focus on identifying activities that target specific movements such as supination or wrist extension. Wearable devices could be used to evaluate the accumulated quantity of movement during waking hours, and the effects of purposeful activities on joint stiffness, pain, function, kinesiophobia and psychosocial outcomes.

9.6 Conclusions

Our study compared the movement yielded during a short session of purposeful activity and ROM exercises in people four to eight weeks after a surgically repaired distal radius fracture. We found that range of movement exercises produced higher volumes of sustained joint position than purposeful activity but that purposeful activity, selected for importance and challenge, produced a higher volume of continuous and variable motion in similar ranges of movement as exercise repetitions. The study challenges therapists to consider the rehabilitative potential of movement produced by purposeful activities for restoring movement and function in the early postoperative weeks.

9.7 Chapter Conclusion

Chapter 9 presented a motion analysis study that evaluated the differences in movement during purposeful activity and ROM exercises. The study produced novel findings that have the potential to change how hand therapists' approach postoperative management of a surgically repaired distal radius fracture. Ranges and amounts of movement achieved during purposeful activity were revealed to be greater than previously thought. It may be that purposeful activities could be used as the predominant approach for restoring ROM after surgery rather than ROM exercises. This represents an exciting new direction for postoperative models of treatment.

The following chapter extends the findings from study IV by presenting researcher observations garnered during data collection. These observations add another layer of understanding to the way that movement is produced during purposeful activity.

Chapter 10 Researcher observations and reflections

10.1 Chapter overview

This chapter presents researcher observations and secondary data from study IV that were not a formal part of the study manuscript. As study IV progressed, I came to realise that my observations and journal entries were rich data that formed a source of knowledge in its own right. I therefore present an informal synthesis of data derived from a visual inspection of the study IV electrogoniometer data and videos, and research journal entries. The purpose of this chapter is to make visible those observations and reflections to add depth to understanding how activities and occupation influences recovery from surgical treatment of a distal radius fracture.

During study III, I had learned to be attentive to the language of my participants and carried that practice through to study IV. I was alert to remarks made by participants in study IV and would frequently make analytic notes in my research journal following data collection sessions. During study IV, video recordings were taken to verify and time-stamp purposeful activities with the electrogoniometry data. During the phase of study IV data analysis and preparation of the study manuscript, I spent time visually inspecting the electrogoniometer data and cross-referencing that data with the videos. As I examined these data, certain patterns, and commonalities of performing purposeful activities became apparent. I had not anticipated the added insights this visual inspection would provide and how reviewing those data would inform my understanding of purposeful activities and exercise. Consistent with critical realism (revealing contexts, mechanisms, and deep meanings), and mixed methodology (data from diverse sources), data gathered through my observations and journal entries contributed much to my understanding of the research question.

This chapter therefore presents an informal synthesis of researcher observations and researcher journaling. The discussion represents observed patterns and commonalities that can give insights about the performance of purposeful activities and their influence on wrist movement, not explored in other parts of my thesis. The synthesis is presented in three sections as my observations about:

the parameters of selected purposeful activities, the differences between purposeful activities and ROM exercises, and the real-time experiences of performing purposeful activities. Concepts arising from these observations and reflections are signalled for later discussion in my integrated discussion Chapter 11 .

10.2 Parameters of self-selected purposeful activities

Study IV involved participants selecting their own purposeful activities. This was a deliberate design feature because a major critique in my first systematic review (study I) was that the purposeful activities in included studies were largely selected by researchers. This negates one of the core tenets of occupation in that the purpose and meaning attributed to occupations should be unique to the individual (Molineux, 2010). Participants in study IV had been given a set of criteria on which to select purposeful activities (light, promote wrist movement, and comfortable to perform at the time of data collection), detailed further in Appendix U. I did not know, however, what other criteria participants might consider when selecting their purposeful activities. Observations of the videos and my journal entries gave some insights about the parameters of activities selected by participants. Detailing these observed parameters may inform future clinical guidelines on safe and therapeutic activity parameters.

The first thing I observed was somewhat surprising. The majority of participants had decided on their activities prior to my arrival and had the necessary materials ready. I was surprised because purposeful activities are not routinely prescribed by hand therapists. In my second systematic review, the parameters of daily activities in the early mobilisation regimes were poorly specified and only one of the studies had used activity as a form of therapy. I had therefore speculated that selecting activities to challenge wrist movement may be an unfamiliar concept for my participants. The fact that most participants had already selected purposeful activities to perform suggested to me that people readily understood the concept of activity providing rehabilitative challenge. A small number of participants had not selected their activities prior to my arrival because they were uncertain about what was *safe* or *permitted*. I discuss this uncertainty further in 10.3, but in this context, once I had discussed options and reassured participants as to safety, all were able to select their own purposeful activities.

Visual inspection of the videos revealed commonalities in the characteristics of the selected purposeful activities in study IV. I have grouped and described these as, non-weight bearing, involved light lifting, challenged wrist movement, did not induce pain, were modifiable, and valued.

10.2.1 Activities were non-weight bearing

When reviewing the videos, I observed that the activities selected by participants did not involve full weight-bearing i.e., loading the wrist with their upper body weight. Some activities involved light loading of the wrist in extension such as when wiping the table, cleaning windows, cutting up vegetables, making a sandwich or gardening, as illustrated in Figure 25 and Figure 26. None involved weight-bearing with full upper body weight or more load than would be expected from a stretch typically performed by people as part of rehabilitation i.e., a brief extension passive stretch to the point of mild discomfort but no pain (Glasgow et al., 2010). Some participants made comments that they chose the activities specifically because they didn't put load through their wrist.

Figure 25

Light loading through the wrist during a food preparation activity

Figure 26

Light loading through the wrist during a gardening activity

10.2.2 Activities involved lifting light loads

I observed that most of the activities involved some lifting. Purposeful activity inherently involves some degree of lifting because it involves the use of objects. The weight of objects was estimated to range from a few grams (plastic containers, light clothing, an empty cup) to 2-3 kgs at most (vegetables, gardening items, laundry basket, watering can) (Figure 27). Two participants who were between six and eight weeks postoperatively performed garden tasks that involved heavier loads or some pulling (Figure 28) but adapted the tasks by pulling or taking most of the load through the non-affected limb.

Figure 27

Light lifting during purposeful activity

Note. Most of the purposeful activities involved very light lifting such as lifting an empty cup or a handful of vegetables

Figure 28

Lifting and pulling during purposeful activities

10.2.3 Activities challenged ROM

I observed that participants often appeared to choose activities that they believed would be good for their wrist. Participants sometimes spoke about how they'd chosen activities that had been challenging to perform over the preceding days and therefore selected those activities for the study. When I reviewed the videos, I could see that participants were often using purposeful activities to attempt wrist movement in the directions of greatest stiffness. Figure 29 and Figure 30 illustrate the way one participant appeared to select activities to challenge the movements of forearm rotation and wrist extension.

Figure 29

Forearm rotation challenge during hair care activity

Figure 30

Wrist extension challenge during dressing activity

I observed on the other hand that for some participants, the activities they selected appeared to deliver minimal challenge to wrist movement. When observing across the videos, it was evident that some activities produced more ROM challenge than others, and that participants varied in how much they used activities to challenge their movement. This highlighted to me that an analytic and collaborative approach would be needed between patient and therapist to match activity challenge with therapeutic goals.

10.2.4 Activities did not induce pain

Inspection of the videos suggested that participants experienced minimal pain during performance of their selected activities. Although participants may not have known for sure whether they would experience pain during the activity, they had been instructed to perform within comfort levels and to stop or take a break if needed. During the recording sessions no participant needed to stop to take a break and I noticed that participants often commented on the lack of pain during performance of purposeful activities. There frequently seemed to be a degree of surprise that it hadn't hurt to perform the activities.

10.2.5 Activities were modifiable

The purposeful activities selected by participants were those that appeared to be modifiable. I observed that the activities were adapted in various ways such as folding only light clothes, taking the majority of the load of an object through the non-affected limb, or applying less force than might normally be used for that task. As an example, one participant chose a gardening activity which involved lifting small rocks and a bag of potting mix. The activity was adapted by putting the majority of the load through the non-operated limb (Figure 28).

A comment from study III of how a participant modified an activity was,

> *I just tried pulling out the weeds and if they were too hard, I stopped and didn't do it or used my other hand.*

10.2.6 Activities were valued

Remarks made by some participants during data collection highlighted that activities were chosen because they were the things that people needed or wanted to do. These activity selections were not arbitrary tasks but were connected to the routines of daily life. Participants had often left the washing that needed folding, dishes that needed drying, or vegetables that needed to be prepared, for the study. Participants were eager to get on and do the normal things of everyday life. Figure 31 illustrates one participant's choice of a valued activity, cleaning windows. When this lady performed the activity, it seemed evident that having sparkling clean windows was very important to her and had been one of life's regular activities for many years. It was insightful to observe how she used an activity that was simultaneously important and challenging for her wrist recovery.

Figure 31

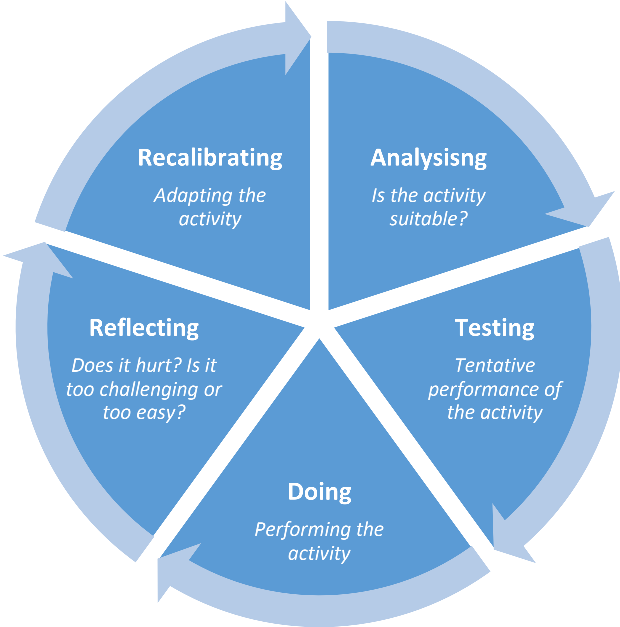
Cleaning windows activity

In this section, I outlined parameters of activities selected by participants. These parameters are important because they gave insights into how participants determined safe activities. My observations suggest that participants were able to intuit parameters of activities congruent with safe loads to a healing fracture i.e., those that challenged movement but did not overload the healing bone. Safe parameters of purposeful activities have not been well specified in the literature and this was clearly demonstrated in study II. The lack of specification may be a reason why purposeful activities are not utilized more in clinical practice as a rehabilitative strategy. It may be that the activity parameters I described here could be used to inform the development of a framework for defining safe activities. I propose such a framework in 11.1.4.

When I reflect on the choices made by most participants, it suggested that participants were unconsciously performing a rudimentary activity analysis. This is discussed in more detail in 11.1, but suggests that, at some level, people were breaking the activity down into its constituent parts to determine the loads, forces and likely pain involved, even if they were not aware that they were doing this. They then tried the activity out and adapted if needed. It could be described as a cycle as illustrated in Figure 32.

Figure 32

Adaptive cycle of activity selection and performance



Note. This cycle illustrates the process of determining and performing purposeful activities.

My observations also prompted me to reflect that maximizing the use of purposeful activities during early mobilisation is likely to require collaboration between patient and therapist. Not all participants chose activities or performed activities in ways that maximized the challenge to wrist movement. When used as a rehabilitative strategy, I foresee that therapists may need to collaborate on selecting activities that match therapeutic goals, perhaps by overtly teaching patients how to utilise the cycle described above. Observing activity performance and offering feedback on maximizing movement during activities may also be a helpful strategy. Observation of activities may be facilitated by having participants bring in objects from a chosen activity or having activity kits in clinics that contain objects needed to perform everyday occupations.

10.3 Differences between purposeful activities and ROM exercises

The analyses in study IV identified statistical differences between purposeful activities and exercises with respect to ROM and movement, and these are documented in Chapter 9 . During the process of reviewing the video recordings from study IV, I observed other differences in movement between the two interventions that were not elucidated by the electrogoniometry data. Although some of these differences were discussed briefly in the study IV manuscript, my observations enabled understanding of the electrogoniometry data through a different lens and I present these here. As with the parameters of purposeful activity described above, such observations can be used to deepen understandings of the mechanisms of purposeful activity and inform clinical recommendations.

10.3.1 More focus on the task than movement during purposeful activity

When watching participants perform purposeful activities and ROM exercises, I noticed there appeared to be less focus on wrist movement during purposeful activity than ROM exercises. Purposeful activities appeared to be performed instinctually, without attending to which joints were moving or how much. In contrast, participants focused on increasing movement during ROM exercises. In Figure 33, it appears that the woman is intent on making a sandwich whereas in Figure 34, she appears more focused on counting repetitions, trying to reach available end range, and ensuring she followed the exercise sequence. During the exercises sessions in study IV there was certainly less informal chat than during purposeful activities. A participant in study III noticed a similar difference by expressing, “when you’re doing exercises that’s all you’re doing, you’re not doing anything else. So, you can push as much or as little as you choose, whereas when you’re performing an activity you might be doing multiple things at once”. This suggests that people may be less likely to focus on producing movement during a purposeful activity than exercises.

Figure 33

Focused on the task of making a sandwich

Figure 34

Focussed on following the exercise instructions and moving the wrist and forearm

This observation presents an interesting dichotomy. On the one hand patients might work harder to produce end range movement during exercises because that is all they're focused on. On the other hand, patients might produce equal end range during activity precisely *because* they aren't focused on it and movement occurs naturally and without effort. A participant in study III described this as 'letting your body do what it knows how to do', illustrating the automaticity inherent in purposeful activity.

Importantly, the results of study IV showed that maximum active end ROM was achieved equally as well during activity as exercise. This suggests that the focused attention of exercise required to achieve end range may not be as important as thought. I noticed during the exercise sessions that although people were focused on producing movement initially, they often lost focus or interest with repeated repetitions. I believe that for some participants, if I had not been there recording, the exercise session might have been hurried along, or completed less thoroughly. Further research that specifically examines the influence of attention on movement would give insights into whether focussed attention is needed to produce end range movement.

10.3.2 Objects and materials facilitated natural, non-forced movement

I noticed when reviewing the videos that once a participant had a familiar object in their hands, movement seemed to be a natural sequela. This makes sense because objects with a specific purpose evoke action. I particularly noticed that for those participants hesitant to move their wrist, picking up an everyday object acted as a stimulus for wrist movement. Additionally, the movement seemed to be natural and not forced. There is a familiarity to activity not evident in exercise. Figure 35 illustrates an example of how manipulating an everyday object facilitated the production of wrist movement. As soon as this woman picked up her clothes airer, wrist movement ensued to enable her to assemble the airer. She had been hesitant to use her wrist but the lifting and holding of a familiar object appeared to promote natural, non-forced movement. With respect to clinical practice, it may be that providing activity kits in clinics that contain a range of everyday objects, could be used as a therapeutic tool for eliciting ROM in the wrist, as an alternative, or adjunct to ROM exercises. Such kits have been proposed and detailed in other studies (Berlet & Kaskutas, 2020; Dy & Yancosek, 2017).

Figure 35

Familiar objects facilitated movement

10.3.3 Purposeful activities facilitated bilateral movement

Another key difference I observed was that movement during activity was predominantly bilateral whereas during ROM exercises movement was unilateral. It made me think about study III where participants often made comments such as, 'you can't floss your teeth one-handed'. Figure 36 and Figure 37 contrast the bilateral nature of purposeful activities with unilateral ROM exercises. Bilateral activities encourage the affected wrist to move because they can't easily be done without using that hand. This could be taken advantage of therapeutically by collaborating with patients to identify purposeful activities that are best performed bilaterally.

Figure 36

Purposeful activities frequently need two hands

Figure 37

Active ROM exercises are usually performed unilaterally

10.3.4 Variable load and effort during purposeful activities

In section 10.2 I discussed that activities usually involved the need to generate force in order to oppose loads, particularly during manipulation of household items. The load frequently varied across the task and included lifting items as light as a few grams up to 2 or 3 kgs. In contrast, ROM exercises involved the generation of force to oppose gravity at most. As discussed in 10.2.1 some activities also delivered loads to the affected wrist at end of range such as during gardening, pressing down on folded clothes, or holding a bread board in place (Figure 25 and Figure 38), and again those forces were variable, light, and occurred as a natural sequela of the task rather than a deliberately performed 'stretch'. I reflected back to study II where people in early mobilised groups regained movement and function sooner that those immobilised for longer than two weeks. I speculated in that study that performing daily activities must have contributed to the superior results of early mobilised groups, but that it was not possible to determine the relative contribution of daily activities (5.2.5). The variable load, force requirements, and ROM I observed during purposeful activities in study IV, may go some way to understanding the contribution of daily activities to recovery of wrist movement. Therapists may think that exercises are needed to deliver sufficient ROM challenge, but observations from study IV caused me to consider that daily activities may deliver movement challenge equally as well, or perhaps better, than ROM exercises for many people.

Figure 38

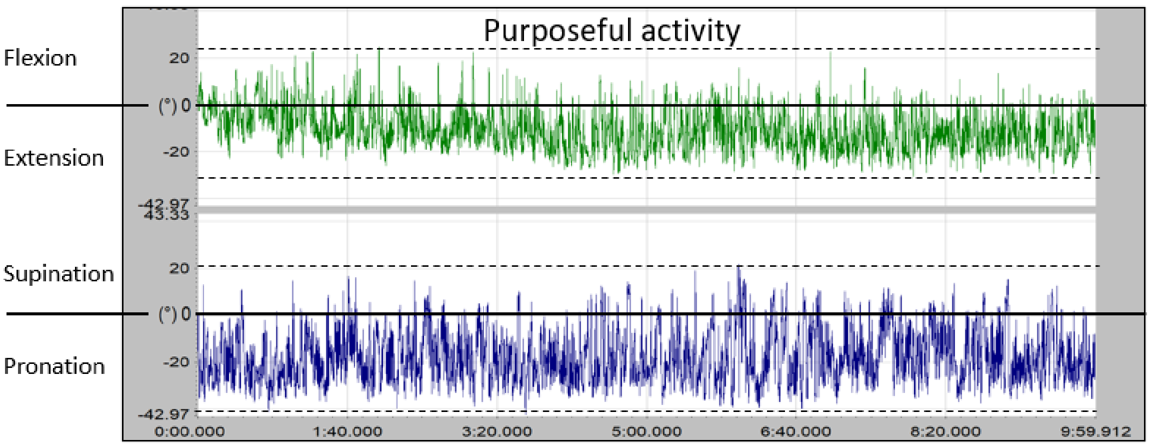
Light passive extension stretch during purposeful activity

10.3.5 More frequent change in direction, speed, and end ROM, during purposeful activity

The final differences, discussed briefly in Chapter 9 , were that purposeful activities appeared to produce more frequent changes in direction and speed, than ROM exercises. Although I did not measure velocity, observation of the data traces showed more short duration, sharp peaks during purposeful activities than ROM exercises, suggesting higher velocity movement. In addition, differences were seen between when maximum ROM was achieved during purposeful activity and ROM exercises. During purposeful activity, movement at or near maximum active end ROM, occurred randomly throughout the 10-munutes. During ROM exercises, end range occurred commensurate with the exercise type i.e., a supination exercise produced end range supination and a wrist extension exercise produced end range wrist extension. These differences are illustrated in Figure 39 and Figure 40. The differences I observed reminded me that variability of movement is a naturally occurring phenomena - it is the way movement occurs in real-life and is the way the wrist needs to move to perform activities. Examples of complex wrist movement planes are dart throwers motion and circumduction. Again, I considered that the variable movement during purposeful activity may play a more valuable role in in regaining normal wrist movement after injury than recognised.

Figure 39

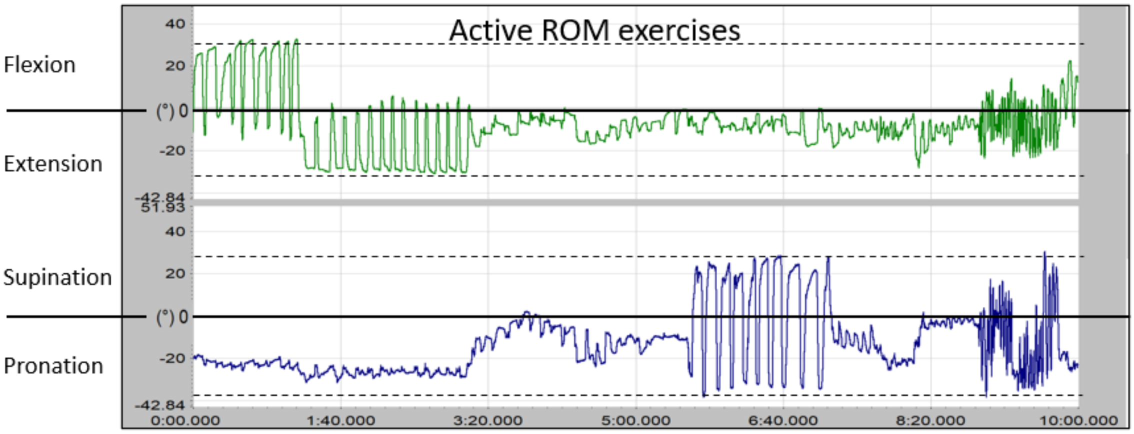
Electrogoniometry trace of purposeful activity for flexion/extension and supination/pronation



Note. The image is of a 10-minute recording for a single participant. End range movement is seen to occur intermittently throughout the ten-minutes.

Figure 40

Electrogoniometry trace of ROM exercises for flexion/extension and supination/pronation



Note. The image is of a 10-minute recording for the same participant as in Figure 39. End range movement is seen to occur in a predictable pattern.

This section has highlighted the concept that movement differs between purposeful activity and ROM exercises. Purposeful activity produced movement that varied more with respect to resistance, force, direction, and speed than ROM exercises. Movement occurred as a response to and was influenced by the objects involved, and the need to use both hands.

10.4 Experiences of performing purposeful activities

During study IV, I observed and listened to experiences of people using their affected wrist during purposeful activities. Comments expressed by participants felt like gold and seemed to be a window into the thought processes of my participants. I would often sit in my car immediately after a data collection visit and record my observations and write analytic notes. In this section I present my observations on the experiences of people performing purposeful activities during study IV. Such observations can deepen understandings of the influence of purposeful activities on wrist movement that may not have been explicitly apparent to participants.

10.4.1 Surprised by capabilities

A delightful observation was the degree to which participants expressed surprise at their capabilities when engaging in purposeful activities. It revealed an unexpected enjoyment and discovery of the capacity to perform activities.

Participants often volunteered after the purposeful activity session that it had been much easier, and they'd achieved a lot more, than expected. They'd thought that doing the activities would be difficult or painful and were surprised to find that the activities felt natural, and doable. Figure 41 illustrates a woman who thought she wouldn't be able to dry the dishes but was pleasantly surprised that she could and that it didn't hurt. Figure 42 shows a woman who was certain it would take 10-minutes to hang out a small basket of washing. Much to her surprise she finished the activity in half the time and had to spend the remainder of the data collection time re-hanging out the same washing! I noticed that participants often expressed an emotive dimension to performing purposeful activities making comments about how amazing it felt to be doing normal activities like folding the washing or that it felt 'good' to be using their wrist.

I also observed instances of participants keeping their hand 'out of the way' and using their non-injured hand in preference, even though they could have used it (Figure 43), and other times choosing to involve the limb (Figure 44). It made me think that people were missing therapeutic 'moments' by being overly protective of their wrist. It caused me to reflect on the concepts of learnt non-use and fear-avoidance and that facilitating people to safely perform purposeful activities in the early weeks after surgery, particularly in movement-hesitant people, may be a helpful strategy for avoiding patterns of non-use (Mehta et al., 2011). Facilitating the selection of activities best performed bilaterally may be helpful in this regard.

Figure 41

Becoming confident

Figure 42

Doing more than expected

Figure 43

Excluding affected limb from purposeful activity

Figure 44

Including affected limb in purposeful activity

10.4.2 Purposeful activity felt like good therapy

Another interesting observation from study IV was participant's discovery of purposeful activity as a form of therapy. After performing activities such as emptying the dishwasher or folding the washing participants seemed to notice that their wrist felt freer or less stiff, and that the activity had felt good for their wrist. I was interested to note that some participants hadn't thought about using purposeful activities such as folding the washing as part of their rehabilitation routines but would now do so (illustrated in Figure 45).

It was not surprising to me that participants may not have considered the therapeutic potential of their daily activities. Daily activities are an implicit, expected part of everyday life that are performed for various reasons but not usually as way to produce movement, or to rehabilitate after surgery. These observations reinforced to me that in clinical practice there is a need to specifically alert people to how routine activities of daily living can be utilised as a formalised component of rehabilitation.

Figure 45

Discovering purposeful activity as therapy

10.4.3 Variable confidence in using affected wrist

I observed during study IV that there were quite stark differences in the degree of confidence participants experienced with using their affected limb. During the recording sessions, most participants carried out their chosen activities with relative ease. There were even some who said they felt a little sneaky because they were ahead of what they'd been advised to do. This made me reflect back to a participant in study III who felt the advice given did not match her capacity.

> *I went there [to hand therapy] and she was giving me the little dumbbells, like a half kg. She was telling me to start exercise with that. And in my mind, I was thinking like, I'm pulling my kids, like each of them, twelve or fifteen kgs. I was already lifting my kids and doing my stuff at home, but I didn't tell her [the hand therapist].*

Although most participants had no difficulty deciding what they wanted to do, there were a small number of people who had not been using their affected wrist and were uncertain what they could do. These participants required supporting strategies such as reassurance of the safety of activities and clarification on which activities might be less demanding to enable confident selection and performance of purposeful activities. Less confident participants often commented they felt safer because a professional was there with them. Figure 46 contrasts confident performance of purposeful activities with a greater hesitance to use the wrist during purposeful activities in Figure 47. Links to videos that illustrate the figures are also included.

Figure 46

Confident to perform daily activities

Gardening and meal preparation.mp4

Figure 47

Hesitant to perform daily activities

Drying dishes and folding laundry_0.mp4

The observation that participants experienced activity as safer because a professional was present caused me to reflect on what strategies therapists could use to help patients feel confident in performing self-directed activities. My impressions are that reticence with activity is compounded by a belief that activity equals harm. Some participants seemed able to interpret discomfort as an expected part of rehabilitation while others were uncertain whether to persevere through discomfort. In study III participants spoke about the variable and sometimes conflicting advice they received about everyday activities from hand surgeons and/or therapists. Advice ranged from 'do what you can', to 'don't do anything except the exercises without the splint'. In the absence of more specific or consistent advice, participants in study III appeared to rely on pain cues and their own intuition during activities.

Undoubtedly, consistent education about safe activity choice and performance would alleviate much of the uncertainty patients experience. In addition, hand therapists could build confidence by teaching activity in similar ways to exercises. Through the process of demonstrating and practicing exercises, we are communicating critical information about the safety and therapeutic value of exercise. On the other hand, we don't 'teach' daily activities. I have observed that as therapists, we often just give general advice and expect patients to go home and be confident to perform daily activities. While this may be sufficient for some patients, it does not enable our more cautious patients. If we were to teach the stages of activity selection and performance, described in Figure 32, patients may be better equipped and more confident to engage in activities and occupation at home.

People's real-time experiences of performing purposeful activities have been presented in this section. Concepts highlighted are a mismatch between perceived and actual ability to perform daily activities and that people quickly grasped the notion of performing purposeful activities as therapy once attention was drawn to that idea. Additionally, it is proposed that education specific to activity performance is likely to enable people to feel confident and safe to engage in activities and occupations away from the hand therapy clinic.

10.5 Summary

In this chapter I presented observations and reflections about the characteristics that typify activities performed during the first eight weeks after surgery for a distal radius fracture, differences between purposeful activities and ROM exercises, and real-time experiences of performing purposeful activities. These are unique data not elucidated elsewhere in my thesis. The observations and reflections have highlighted concepts that add depth to my understandings about the clinical utility of purposeful activities and occupation as therapy. I intend to discuss and integrate these concepts along with findings from studies I-IV in Chapter 11 . In particular I have signalled the following concepts:

- There are specific parameters of daily activities people apply when self-determining safe activities that may inform the development of a framework for safe postoperative activities.
- Movement appears to differ when it is produced by purposeful activity compared with ROM exercises. Purposeful activity produces movement that varies more with respect to resistance, load, direction, and speed, than ROM exercises.
- Movement occurs as a response to, and is influenced by, the objects involved and the demands of the task.
- Activity-specific education may build confidence in selecting and performing daily activities and minimise the mismatch between perceived and actual capabilities.
- Most people appear capable of self-selecting activities commensurate with bone healing phases and that challenge wrist movement. Education that is specific to activity performance is likely to further enable people to feel confident and safe.
- Patient/therapist collaboration may help to ensure that therapeutic opportunities during daily activities are maximised.

Chapter 11 Integrated discussion

In this chapter I return to my overarching research question: how does activity and occupation influence recovery of movement after a surgically treated distal radius fracture? To answer the question, I discuss the integrated findings from across this thesis. Because little was known about my research question, I chose to use a mixed methodology approach that allowed me to approach the research question from divergent angles. Part of the quote by Janet Frame (1979), at the beginning of this thesis illustrates the intention of this chapter, "A sentence which, travelling, looks out of portholes as far as horizons and beyond is good" (p.47). Each of my studies looks out of a porthole bringing new knowledge. I intend bringing that knowledge together to look towards the rehabilitation horizon of an occupationally-based rehabilitation approach that harnesses the complexity and unique characteristics of occupation in bringing about improvements after a wrist injury.

My research has added novel knowledge in two distinct arenas. First, I have deepened theoretical understandings of the complex mechanisms through which activity and occupation facilitates recovery from a surgically repaired distal radius fracture in the early postoperative period: eliciting substantial joint movement and building psychosocial resources. Second, I have shown occupation to be a complex, multi-faceted rehabilitative strategy that may be used to facilitate recovery. Based on my research findings, I propose an occupation-based postoperative rehabilitation approach.

I will first discuss the features and strengths of my thesis, provide a summary of the studies, then present four points that integrate the key findings from my research. The remainder of the chapter is a discussion of these points. The final section presents limitations of the research and suggestions for future directions.

A unique feature of this doctoral work is that I sought to understand the underlying mechanisms by which activity and occupation brings about change. Much of the occupation-focussed research in hand therapy evaluates the effects of occupation-based interventions but many of these studies fail to provide a robust theory for the intervention or describe the iterative process by which the intervention was developed (Bleijenberg et al., 2018). Another strength of my research is that the data were collected when participants were in the proliferative (day 5 to weeks 3-4 postoperatively), and early remodelling (week 4-8 postoperatively) phases of bone healing. To my knowledge there are no other studies that have evaluated wrist movement in an early postoperative population and my research is therefore valuable for informing postoperative fracture management. Another strength is that I took a 'real-world' approach by conducting data collection in the homes of participants rather than in outpatient clinics or research laboratories. The data are therefore authentic to how people perform activities in everyday life after surgery and therefore have direct applicability to rehabilitation.

The studies presented in this thesis include two systematic reviews, an Interpretive Description qualitative study, and a motion analysis study using a randomised crossover design. In addition, a synthesis of secondary data from observations and critical reflections are included. The studies and secondary data are summarised in Table 23 providing an overview of the purpose, methods, and main findings of each study.

Table 23

Summary of thesis studies and secondary observational data

Study	Purpose	Methods	Main findings
I, (Chapter 4)	Investigated the influence of purposeful activities on motor performance of the upper extremity	A systematic review of 21 studies that compared motor performance during purposeful and nonpurposeful activities	People performed more movement repetitions and performed for longer periods of time during purposeful activities. Movement was more likely to be smoother, more controlled, and quicker
II, (Chapter 5	Investigated, early mobilisation recommendations with respect to daily activities, and the efficacy and safety of early vs. delayed mobilisation	A systematic review of 8 studies that explored how daily activity is recommended, and compared early and delayed mobilisation	Daily activities were commonly recommended as part of early mobilisation but poorly specified. Mobilising before 2 weeks was safe and had better short term outcomes compared with ≥ 2 weeks
III, (Chapter 6 Chapter 7	Explored the perceptions and experiences of people about how daily activities and occupations influenced recovery after surgical treatment of distal radius fracture	A qualitative study using Interpretive Description methodology. Semi-structured interviews of 21 adults, used reflexive thematic analysis	Daily activities were perceived to facilitate postoperative recovery by: (i) driving the rehabilitative process, (ii) offering ready-to-hand challenges, (iii) promoting intentional use, (iv) habituating to movement and (iv) building psychosocial resources
IV, (Chapter 8 Chapter 9	Evaluated and compared movement during purposeful activity and ROM exercises	An exploratory biomechanical study utilising a randomised crossover design, 35 adults with a surgically repaired distal radius fracture	ROM exercises produced higher volumes of sustained joint position. Activities produced higher volumes of continuous, repetitious movement in equivalent ranges as exercise repetitions
Observations and critical reflections (Chapter 10	To further understandings on how activities facilitate recovery from surgical treatment of a distal radius fracture	Observations from inspection of electrogoniometer and video data, and research journal entries. Parameters of self-selected purposeful activities and differences between purposeful activities and exercises were outlined. Observations of real-time experiences revealed variable confidence and a mismatch between actual and perceived abilities.	

Four points integrate and summarise the novel knowledge my thesis has elucidated. Each of these four points represents a key contribution to the existing knowledge about the role of occupation in recovery from a surgically repaired distal radius fracture. In the following sections I expand on each point, drawing on findings from my research, and contextualise the findings within the wider body of research.

1. Activity during early rehabilitation is safe and appropriately self-determined. People are able to select daily activities that challenge ROM and function, particularly when supported by education that advocates and encourages performance of safe activities. I propose a framework for defining safe activity parameters.
2. Purposeful activity produces large ranges and amounts of wrist and forearm movement. Range and amount of wrist movement during purposeful activities is equivalent to or greater than during ROM exercises. Movement is characterised by variability in range, speed, and load. I highlight key characteristics of occupation that facilitate the production of movement: recurring therapeutic opportunities, varying intensity of task demands, manipulation of objects, and bilaterality requirements.
3. Activity and occupation play a strategic role in building psychosocial resources in the early weeks of rehabilitation. Occupation potentiates motivation, engenders wellbeing, reclaims normality, and builds a sense of accomplishment and optimism.
4. Occupation is a powerful rehabilitative strategy for restoration of movement and function. A comprehensive occupation-based rehabilitation approach that utilises the complex influences of occupation on movement and psychosocial capabilities is proposed.

11.1 Activity during early rehabilitation is safe and appropriately self-determined

My research elucidates the safety of performing daily activities in the early postoperative weeks. I show that people are able to appropriately determine daily activities that challenge ROM and function, particularly when supported by education that advocates and encourages performance of safe activities. I propose a framework for defining safe activity parameters.

11.1.1 Active use during the proliferative and early remodelling phases

My research challenges clinicians to use activity as a therapeutic strategy. To use activity in the early weeks after surgery, clinicians must be confident that activities will not overload healing bone and that patients can safely modulate activity performance. In chapter 3.2.5 I reviewed biomechanical studies that evaluated the strength of volar locking plates used to surgically treat distal radius fractures. This body of work consistently demonstrated that volar plates are sufficiently strong to withstand the forces of early mobilisation and active use (Alluri et al., 2015; Kamei et al., 2010; Quadlbauer et al., 2020). In study II I showed that active use of the wrist within two weeks of volar plating of a distal radius fracture is considered safe and widely recommended. The safety of commencing daily activities within two weeks of surgery is further evidenced by primary research (Ghaddaf et al., 2021; Gutiérrez-Espinoza et al., 2021; Zeckey et al., 2020) and expert opinion (Kooner & Grewal, 2021; Quadlbauer et al., 2020).

Research highlights nonetheless, that a wariness about commencing early active mobilisation and active use persists in clinical practice, revealing a gap between evidence and practice (Salibian et al., 2019). Hand surgeons and therapists may be overly protective in their approach to rehabilitating a surgically treated distal radius fracture (Quadlbauer et al., 2020). Such reticence towards early active use may stem from traditionally restrictive postoperative protocols and tensions with adopting early mobilisation approaches (Daud, Yau, Barnett, & Judd, 2016; Stephens et al., 2020). Therapists may distrust their patient's ability to determine safe activities or perceive that protective splints are needed for pain, psychological support, or protection if a fall occurred (Zeckey et al., 2020). Translating research into clinical practice takes many years and unlearning traditional patterns of practice can create tensions for clinicians (Gupta et al., 2017; Morris et al., 2011), thus explaining the delayed uptake of advocating early active use. My research challenges the reticence towards advocating daily activities in the early postoperative period. Such perspectives do not appear to be evidence-based and present a barrier for using activity as a rehabilitative strategy.

From the perspective of patients, my research shows that people with a surgically treated distal radius fracture similarly express wariness towards early active use of their affected wrist. In study III, participant narratives revealed frequent concerns that using their affected wrist might damage the metalware or bone. My observations of participants in study IV, also suggested a hesitancy and uncertainty by some towards performing purposeful activities. A recent qualitative study found that around one third of participants reported wariness about using their affected wrist after early cast removal following a surgically treated distal radius fracture (Watson, Martin, et al., 2018). It has been suggested that patient anxiety about active use of an operated wrist is likely based on societal perceptions that injuries require immobilisation or conflicting advice from clinicians about daily activities (Watson, Martin, et al., 2018). Such patient perspectives that daily activities are potentially harmful, reinforce the need to provide clear advice about safe activity selection and performance.

11.1.2 Ability to determine safe activity

A key contribution of my research is describing the process by which people determine safe activities. As noted above, and from my own clinical observations, therapists may distrust their patient's ability to modulate safe activities. Most participants in my studies however, had a tenacious, intuitive ability to decide on what activities were safe. This challenges the perspective that patients may choose unsafe activities. I modelled the process used by participants to select activities in Figure 32, an adaptive cycle of analysing, testing, doing, reflecting, and recalibrating. In the occupational therapy literature, this process is similar to activity synthesis, the breaking down of an activity into its constituent parts and adapting it to allow successful performance (Kramer & Hinojosa, 2014). In everyday life, people continually adapt, adjust, and create activities to align with their physical and psychosocial capacities (Kramer & Hinojosa, 2014). It is not surprising that patients use the same strategies when faced with the challenge of a broken wrist. I modelled the adaptive cycle of activity selection and performance (Figure 32) as a potential tool for teaching patients about early active use after surgery, particularly for those demonstrating activity aversion.

11.1.3 Activity-specific education

In my studies, I found that participant performance of daily activities was enabled by activity-specific education. After surgery, people rely on rehabilitative advice from surgeons and therapists but are often frustrated by lack of or conflicting advice (Claydon et al., 2017; Watson, Martin, et al., 2018). Studies have consistently shown that reliable, trustworthy education helps reduce negative cognitions and perceptions, improves engagement in rehabilitation, and improves self-efficacy (Andreasson et al., 2020; Claydon et al., 2017; Mehta et al., 2011; Stenner et al., 2018; Watson, Martin, et al., 2018). I propose strategies that may facilitate activity-specific education. These strategies arose from my analysis of narratives in study III including the use of occupationally positive language, patient collaboration, and the use of activity kits.

The manner in which ideas are communicated is crucial (Vranceanu et al., 2009) and the use of negative language can disengage patients from therapy and maintain unhelpful perceptions (Mehta et al., 2011). Occupationally positive language that frames activities and occupations as beneficial for recovery and an expected component of postoperative rehabilitation, is likely to enhance patient's engagement with activity.

Examples of occupationally negative language might be:

> Be very careful about what you do because it might make your pain or swelling worse. The bone is still quite fragile, and you shouldn't lift anything heavier than a cup of tea.

Examples of occupationally positive language might be:

> There are two ways you can work on regaining movement in your wrist, performing everyday activities and exercises, today I will talk to you about both.
>
> Using your hand for light activities is very good for your wrist. People say they feel better when they do some everyday activities, and research shows that you will get a lot of beneficial movement in your wrist during everyday activities.

Another approach to endorsing activity performance is to regularly collaborate on therapeutic goals, identify activities that can match those goals and discuss how to appropriately grade activities. Research has shown that when a collaborative approach is taken during rehabilitation, patients take more control of their own recovery, disability is minimised, and psychosocial outcomes improved (Jayakumar et al., 2020; Stern et al., 2021). Good examples of collaboration after distal radius fracture are the randomised studies by Watson, Haines, et al. (2018) and Hansen et al. (2020) where activities were selected and graded for challenge and performance between patient and therapist.

Education might also be enhanced by practicing and receiving feedback using activity kits or the patients' own objects/materials. Some participants in study III remarked that they would have found it helpful to practice some activities under the guidance of a hand therapist, particularly in the early weeks of rehabilitation when they were lacking confidence to move their wrist during activities. Activity kits such as those described in the literature could be used (Berlet & Kaskutas, 2020; Dy & Yancosek, 2017), or clinics could assemble materials most suited to their patient population. Practicing an activity with a therapist observing communicates critical information that such activities are safe and important, thereby building confidence and competence to carry out the same activities at home. This may be particularly helpful for patients anxious about using their affected wrist.

11.1.4 Parameters of safe activity

Therapists' reluctance to use purposeful activity as a therapeutic tool may be because they are uncertain how to recommend or define safe activity. I propose a framework for defining safe activity that may be used by therapists for educating patients. The framework is based on recommendations from study II (Table 7 and 5.2.5) participant narratives in study III (7.2.8), purposeful activity choices in study III (Table 12) and study IV (Table 19), research that advocates for early active use (Brehmer & Husband, 2014; Ghaddaf et al., 2021), and hand therapy texts (Naughton & Algar, 2021). My observations from study IV outlined in 10.2 also feed into the development of this framework. The parameters apply to activities performed between weeks two and six following surgery when early bone healing is occurring. During this phase the surgical implant (volar locking plate) is providing stability for the fracture rather than the bone itself and greater care is required to avoid loss of fracture reduction (Smith et al., 2004). The framework requires future scrutiny by experts in hand rehabilitation to support transition of my findings into clinical practice. The parameters of safe activities outlined in this framework are: valued, provide appropriate challenge, comfortable to perform, non-weight-bearing, involve non-forceful grip, and involve only light lifting. An overview of each parameter included in the proposed framework is provided below:

Valued

First and foremost, activities should be selected by participants. Purposeful activities should be something the person wants, needs, or is expected to do, and is perceived to bring satisfaction or improved capacity (Bigelius et al., 2010; Polatajko & Davis, 2012).

Provide appropriate challenge

Activities chosen should be those that appropriately challenge ROM and functional use. Activities should encourage movement in multiple directions, targeting directions of greatest stiffness where possible. In order for activities to provide the right amount of challenge, the activities chosen should be able to be graded up or down to avoid over or underloading the healing tissues (Price & Miner, 2007). Grading of the challenge provided by activities may involve manipulation of amount (duration and repetitions), speed of movement, ROM, parameters of objects (weight, size, pliability), or accuracy and co-ordination requirements. It may be useful to educate people on optimal dosage using language suggested by Brody (2012), "you have a certain number of activity dollars each day to spend on all your work, leisure, home care and therapy activities; therefore, if one of these areas increases, other areas will have to decrease." The adaptive cycle of activity selection and performance Figure 32 can also be used to educate patients on how to modify tasks.

Comfortable to perform

My framework suggests that activities should not cause immediate or lasting pain but may be slightly uncomfortable. People can be encouraged to work up to and slightly beyond their discomfort limits during activity, in order to provide movement challenge but avoid overloading the healing bone (Quadlbauer et al., 2020).

Non-weight-bearing

Activities should be those that do not involve forceful leaning on the wrist. Literature varies as to when weight-bearing can be introduced, from as early as two weeks (Andrade-Silva et al., 2018; Clementsen et al., 2019), to six to eight weeks after surgery (Naughton & Algar, 2021). My framework suggests that light weight bearing during activity is introduced from two weeks as tolerated such as may occur when pressing down on folded laundry, or when making a sandwich. The force applied should be no more than would be expected from a wrist extension stretch, which the therapist can demonstrate.

Non-forceful grip

To avoid failure of a surgical volar plate, grip forces during activity are often recommended as not exceeding 17 kg during early rehabilitation (Brehmer & Husband, 2014; Naughton & Algar, 2021) based on the biomechanical work of Putnam et al. (2000). Given that most people would not have grip strength of 17kg in the early weeks after surgery (Brehmer & Husband, 2014), limits on grip may be unnecessary, however may be useful with people at risk of exceeding such limits. Participants in studies III and IV selected activities that did not involve painful or forceful grip demonstrating an intuitive ability to self-regulate grip forces. My framework suggests that gripping during activity is self-determined according to tolerance but to a maximum of 17 kg. People can be educated as to what 17 kg represents by gripping a dynamometer in the non-affected hand.

Light

The term light activity is poorly specified in the literature and there are few specific guidelines as to what constitutes a light activity. Clinically, it is often said that people should not lift anything any heavier than a cup of tea initially, but this is not widely reported in the literature. Only two studies in my second systematic review (study II) specified weight restrictions during activity, from <1 kg to <2.5 kg (Quadlbauer et al., 2017; Valdes, 2009). Tolerated weights are likely to vary between individuals so specifying weights may be unhelpful. My framework suggests that people can lift light objects according to tolerance, within sensible limits. Therapists can give examples of everyday objects to illustrate the principle such as lifting small clothing, plastic containers, one or two plates, or a laptop or tablet.

11.2 Purposeful activity produces high ranges and amounts of movement.

My research provides novel evidence that purposeful activity produces large ranges and amounts of wrist and forearm movement. Movement is characterised by variability in range, speed, and load. Key characteristics of occupation facilitate the production of movement: recurring therapeutic opportunities, varying intensity of task demands, manipulation of objects, and bilaterality requirements.

11.2.1 Ranges and volume of movement

An important contribution of my research to the body of knowledge on occupation as a therapeutic tool, is the quantification of movement during purposeful activity. My research revealed that purposeful activities produce larger ranges and amounts of movement than previously understood. First, I showed in study IV, that wrist range of movement was equivalent during purposeful activity or ROM exercises and that the amount of wrist movement undertaken close to available end range was greater during purposeful activities. These are novel findings, challenging traditional perceptions that exercises are more efficient at eliciting end of range movement than daily activities (Gracia-Ibáñez et al., 2017). Second, my findings demonstrate much higher amounts of movement during purposeful activities than ROM exercises. Therapists are challenged to take note of the considerable potential of purposeful activities to elicit high therapeutic dosage of wrist and forearm movement, during waking hours. The findings challenge traditionally held perspectives about activity and point to the potential of purposeful activities as a therapy for restoring movement after surgery of a distal radius fracture.

The finding that purposeful activity produces movement with therapeutic potential is corroborated by my other studies. Study I found that greater movement volume was elicited during purposeful activities than during non-purposeful tasks. Study II showed that people who used their wrist during daily activities by two weeks after surgery achieved an earlier recovery of movement and function than people who were immobilised for longer than two weeks. In study III, participants perceived a positive relationship between activity and wrist movement. People observed that the more they used their wrist the more quickly their ROM and function returned. Taken together my research challenges the reliance on ROM exercises as the predominant rehabilitative approach. In this chapter I suggest a new way of approaching rehabilitation based on the findings of my studies. The proposed approach is outlined in 11.4.2.

Exercises have long been the primary approach for promoting wrist movement in the early weeks after a surgically repaired distal radius fracture (Smith et al., 2004). While there is a move towards early active use of the affected hand during daily activities (Kooner & Grewal, 2021; Quadlbauer et al., 2020), exercises remain the mainstay of early postoperative rehabilitation (Naughton & Algar, 2021) and studies rarely describe how to use occupation as a strategy for restoring wrist movement. The influence of exercise interventions in restoring movement may not be as great as commonly perceived, however. Studies have suggested that exercises may be no more effective in improving movement following upper extremity fracture than moving the limb during everyday living (Bruder et al., 2017). Other authors have proposed that encouraging active use is as effective as formalised therapy for most people after surgically treated distal radius fracture (Chung et al., 2019; Kooner & Grewal, 2021).

It has been suggested that exercise may be less effective than thought, because the dosage of movement achieved during intermittent exercise sessions is unlikely to equal that produced by normal use of the limb (Bruder et al., 2017). As such, exercises in isolation are unlikely to deliver sufficient movement dosage to remodel shortened or tight tissues (Bruder et al., 2017). On the other hand, active motion may be sufficient to increase the mobility of a stiff joint, provided the load does not exceed the capacity of the tissues to tolerate that load (Glasgow et al., 2010; Midgley & Pisano, 2021). My research shows that purposeful activity has the potential to deliver large doses of low load movement and may explain why people achieve better outcomes when activity is encouraged during early mobilisation.

11.2.2 Occupation has distinct characteristics that facilitate the production of movement

My research has highlighted unique characteristics of occupation that facilitate the production of movement: recurring opportunities for both automatic and intentional movement, varying intensity of task demands, manipulation of objects, and bilaterality requirements.

Study III and IV showed that an important mechanism of occupation in producing movement is that movement opportunities are ‘ready-to-hand’. While it seems obvious that occupation creates multiple opportunities for therapeutic movement, this is not widely written about in the literature. It may be because occupation is so tacit and performed with minimal awareness (Hinojosa & Blount, 2014b), that therapists and patients alike, forget that occupation is a rich source of movement. Patients could be performing considerably more wrist movement than would occur during intermittent exercise sessions if the awareness of those opportunities were brought to the fore. In addition, because study IV showed that ROM produced during purposeful activities was equivalent to ROM produced during exercises, therapists can be confident that substantial dosage of end, and near end, range of movement may be achieved during purposeful activities.

In 10.3.4 I presented data showing how resistance and force were more variable during purposeful activities and that movement is facilitated through the objects and demands of the task. The value that objects offer for a potential action is referred to as object affordance. Systematic reviews have concluded that adding an object to a movement enhances the quality and quantity of motor performance (Hétu & Mercier, 2012; Wu et al., 1998). Additionally, it is suggested that movement is more efficient when people select or use their own objects rather than unfamiliar objects (Holubar & Rice, 2006; Sackaloo et al., 2015). The bilateral nature of activities also fosters movement. Studies have shown equivalent use of the dominant and non-dominant hand in healthy adults during a 24 hour period (Bailey et al., 2015), suggesting the value of everyday tasks in promoting use of both limbs. In clinical practice, patients could be encouraged to use objects that involve light lifting and low force grip, focus on performing bilateral tasks and introduce variety into activity types.

11.2.3 Occupation influences sensorimotor function

With respect to influencing movement, my research also suggested a role for purposeful activities in restoring sensorimotor function. Study III revealed some interesting observations about sensorimotor disruptions. Participants frequently described their initial movement during activity as feeling weird, robotic, or unnatural, and that movement and awareness of the hand had to be relearned. Similar perceptions were reported in a recent qualitative study in the same population (Stern et al., 2021). Participants in study III also noticed that repetition of purposeful activities helped to restore the perception of normal movement and integrated the limb into normal body schema. It is well-understood that active use drives cortical plasticity and helps to restore normal sensorimotor function after injury, the principle of 'use it and improve it' (Kleim & Jones, 2008; Wollstein et al., 2018). Repetitious performance of meaningful real-world activities could be taken greater advantage of in restoring sensorimotor function, similar to how task-oriented therapy is used in neurorehabilitation (Levin & Demers, 2021; Muratori et al., 2013). It has been suggested that substantial repetitions of rehabilitation activities may be needed to sustain improvements in movement and function (Kleim & Jones, 2008). An occupation-based rehabilitation approach could include selecting activities which emphasise sensorimotor function, and utilise therapeutic strategies to promote recovery of proprioception, kinaesthesia and body schema (Hagert et al., 2021; Levin & Demers, 2021). As an example, while folding the washing, a person could use strategies such as attending to the texture differences between garments, and calibrating proprioception with and without visual feedback. While drying dishes, patients could be instructed to observe and focus on what movement feels like in the non-affected wrist and project that perception onto the affected wrist as an imagery exercise. Such activities may have more meaning to people than tasks frequently described in proprioceptive retraining programmes such as sliding a towel on a wall, or air-drawing with a chopstick (Hagert et al., 2021). There is also some evidence to suggest that motor imagery and action observation training may be beneficial in reducing pain intensity in people with postoperative pain (Suso-Martí et al., 2020).

11.3 Activity and occupation build psychosocial resources

Another important contribution of my thesis is showing that activity and occupation builds psychosocial resources in the early weeks of rehabilitation. I have elucidated that performing purposeful activities potentiates motivation, engenders wellbeing, reclaims normality, and builds a sense of accomplishment and optimism.

11.3.1 Occupation potentiates motivation

Occupation as a potentiator of motivation is evidenced in my research. In study III, people with a surgically treated distal radius fracture described occupation as a driving force of recovery, that the desire to return to valued occupations acted as an impetus to actively engage in the recovery process (page 124). Participants described in emotive language their desire to return to occupations such as fishing, creative pursuits, motorbike riding, or dance, and equally their fear that they may not be able to do so. Valued occupations such as these provided a source of positive energy and motivation to keep going during the difficult early weeks of rehabilitation.

Daily activities were also shown to provide a scaffold for motivation. Early after surgery participants who performed simple tasks, even while in a cast, developed an expectation that the hand was available for use. When the cast was removed, participants were motivated to involve the wrist in activities because the pattern of active use had been established. Fostering early active use may help to avoid patterns of disuse commonly seen after distal radius fracture (Mehta et al., 2011). Observations from study IV further confirmed the role of occupation in potentiating motivation. During study IV, I noticed a frequent mismatch between perceived and actual ability to perform purposeful activities. Once participants discovered their capacity for activity performance however, there was an effect of spurring on to greater use of the affected limb.

Occupation additionally builds motivation in the early weeks of recovery through successful completion of graded down daily activities. My findings corroborate research that identified occupation as a source of motivation during recovery from hand injury (Bates & Mason, 2014; Colaianni & Provident, 2010; Lequerica et al., 2009), but go further in showing the potency of occupation as a motivational force in early recovery. I have highlighted the powerful influence of valued occupations as an underpinning motivational force from the earliest phases of rehabilitation. Helping patients to identify those drivers may be particularly important for people struggling to actively engage in early rehabilitation.

11.3.2 Occupation engenders wellbeing, reclaims normality, and builds a sense of accomplishment and optimism.

A recurring theme in my research is the way that occupation positively influences wellbeing and builds capabilities. In study III, when people began to perform daily activities, they felt better, and experienced more optimistic feelings about the future. It appeared that the very act of doing, alleviated feelings of loss, uselessness, and anxiety about the future. During study IV, I observed similar responses to purposeful activities. Participants frequently remarked on the positive emotions that performing activities engendered. Achieving simple activities prompted people to try more complex challenges. As experiences of success grew, so did a sense of optimism, and a perception that life was returning to normal. My research highlights the need to enable successful activity performance. This may be particularly important for activity-averse patients. Narratives from participants in study III revealed how they used their own psychosocial resources such as physical exercise, mindfulness practices, and determination, to help them re-engage with normal routines and cope with the disruptive nature of injury.

After fracture or hand injury, people consistently describe a strong desire to regain a sense of normality, return to usual activities, and not be a burden on family and friends (Bates & Mason, 2014; Claydon et al., 2017; Smith-Forbes et al., 2016; Stern et al., 2021). Other studies have reported similar findings, that resuming daily activities and occupation after hand injury restored a sense of identity, normality, and feelings of accomplishment (Ammann et al., 2012; Bates

& Mason, 2014; Kingston et al., 2014; Stern et al., 2021). These studies, however, did not always take the next step in suggesting ways that occupation could be used as a therapeutic tool for building psychosocial resources.

A postoperative rehabilitation approach informed by my research should directly use purposeful activities to build psychosocial competencies. Creating the context for people to experience successful completion of purposeful activities is essential. Drawing from my findings, an important strategy should be educative: highlighting to patients the influence activity performance will have on motivation, wellbeing, and accomplishment. Analysis of narratives from study III suggested strategies that can build psychosocial competencies. These include identifying those occupations that will serve as drivers of motivation during recovery, identifying a patient's own psychosocial resources and harnessing them to support recovery, performing graded down activities in the immediate postoperative period to build early competence and resilience, enabling those activities that are most likely to contribute to feelings of wellbeing, and selecting activities that match and appropriately challenge physiologic capabilities to ensure success and mastery.

11.4 Occupation is a powerful rehabilitative strategy

When I introduced myself as a researcher in chapter 2.1 I discussed that occupation is immutable and that rehabilitation occurs in the messiness of life. I wanted to explore how the ordinary activities of daily life could be better harnessed to facilitate recovery from surgical treatment of a distal radius fracture. I have demonstrated that occupation is a complex construct that acts in multiple ways to influence recovery from a surgically repaired distal radius fracture.

I now draw together the key learnings from my doctoral work to inform an occupation-based rehabilitative approach that utilises the complex potentiating effects of occupation on producing movement and building psychosocial capabilities. This approach moves away from traditional models that focus on protection, intermittent ROM through exercise routines and strict limits on activity performance. The main principles of the approach are that it harnesses the unique mechanisms of purposeful activity in producing changes in wrist movement and function, facilitates early engagement in occupation to build psychosocial capabilities, builds on the inherent capacity of patients to self-direct activity selection and performance, and uses patient/therapist collaboration to assist in matching therapeutic goals with targeted activities. Occupation is promoted as the primary tool for producing active movement, and ROM during daily activities is encouraged throughout the day. Therapies for resolving oedema, joint stiffness, or hypersensitivity such as exercise, splinting, manual therapy, or desensitisation remain important, and are used as needed.

I will first outline components of purposeful activity as a therapeutic tool, present a table that describes the elements of an occupation-based rehabilitation approach and discuss future steps to be taken in the full development of such an approach.

11.4.1 The therapeutic use of activity

As described earlier in this thesis (3.3.1) the term purposeful activity denotes that a person is actively performing a personally meaningful, useful activity as the primary tool for facilitating change in capabilities (Fisher, 2014; Hinojosa & Blount, 2014a; Nielsen et al., 2020). To use purposeful activity as a therapeutic tool it is necessary to ensure that the activities are valued and have meaning to the person, that they occur naturally within the person's life, and that they provide adequate challenge for producing change (Hinojosa & Blount, 2014b). These three activity tenets are assumed in the approach I am proposing.

Value and meaning

Purposeful activities should be something the person wants, needs, or is expected to do, and is perceived to bring satisfaction or improved capacity (Bigelius et al., 2010; Polatajko & Davis, 2012). There must be a sense of autonomy, choice and intentional engagement (Crabtree, 2010; Law, 2002). Studies III and IV highlighted a broad range of activities that people performed. Often the first activities were those essential to daily life such as getting dressed, showering, eating, childcare, and household tasks. Participants also spoke about how important it was for their wellbeing to engage in enjoyed activities in the early weeks of recovery, such as playing a musical instrument, gardening, or physical exercises. Therapists should use both essential and enjoyed activities as therapeutic tools.

Naturalistic

Purposeful activities should be performed in the way they would normally occur in the person's everyday life (Pierce, 2001). Maintaining the integrity of the activities in context means that patients are not required to transfer a simulated experience to the challenge as it will occur at home or work (Pierce, 2001). As previously discussed, activity kits have utility for practice and for providing feedback to participants on performing activities in an appropriately challenging manner. Activity kits should as much as possible use familiar materials and processes (Hinojosa & Blount, 2014b). My approach promotes the use of authentic purposeful activities as the main component, using activity kits as supporting educative and teaching strategies.

Challenging

Purposeful activity needs to provide a 'just-right' challenge that targets a collaboratively developed goal (Fisher, 2014; Hinojosa & Blount, 2014b; Price & Miner, 2007). Recurring, narrative micro-negotiations can occur at each hand therapy visit to review goals and define appropriately challenging activities (Price & Miner, 2007). For a purposeful activity to provide the right amount of challenge an activity may need to be graded up or down (Price & Miner, 2007). This involves modifying the complexity and components of a task to allow successful completion (Perlman & Bergthorson, 2017). My research shows that people intuitively grade activities for complexity but may also benefit from specific education to ensure that an activity neither under nor overloads healing tissues.

11.4.2 An occupation-based rehabilitation approach

Table 24 is the first iteration of a proposed occupation-based approach. The approach is primarily intended for use with people who have had surgical treatment of a distal radius fracture but is likely to have applicability for the rehabilitation of other wrist and hand conditions. The elements of the approach are tabulated and described as three components: activity-specific education, in-clinic practice and collaboration, and home-based selection and performance of purposeful activities. The three components are not necessarily sequential. The table is for therapists to understand the components of the approach, practice examples, and to form the basis for developing training programmes and resources. The table is not a resource for patients, separate patient-focused materials would need to be developed to support the approach.

Table 24

Elements of an occupation-based approach for rehabilitation of surgically repaired distal radius fractures during the first six weeks

Component	Principle	Content	Actions
Activity-specific education	Daily activities are safe	Defining the performance of daily activities as safe	The therapist will deliver education about the safety of performing daily activities in the early postoperative weeks to patients.
		Defining the parameters of safe activity	The parameters of safe activities are discussed with patients by the hand therapist. The activity parameters are detailed in 11.1.4: valued, non-weight-bearing, light, non-forceful grip, non-pain inducing, modifiable, and challenging.
	Purposeful activities promote wrist and forearm movement	Performing purposeful activities will produce substantial wrist movement	Discuss with patients how performing purposeful activities promotes multiple repetitions, facilitates movement to the end of available range, makes the wrist move more than during exercise and that purposeful activities present multiple occurring opportunities for movement.
		Facilitate automatic movement	Highlight that some movement will happen automatically when performing activities that present themselves during the day and that deliberate attention is not always required.
		Facilitate intentional performance	Highlight that patients will also need to look for opportunities and make deliberate choices to involve the affected hand. That they may need to consciously 'remember' to move their affected wrist during activity or chose tasks that require bilateral use.
		First experiences of movement may be unpleasant	Advising patients that initial movement during activities might feel weird or unpleasant and providing reassurance that repetition and practice will help to normalise movement and lessen discomfort.
	Enabling early performance of	Benefit of activity on wellbeing outcomes	Draw attention to the positive influence activity performance will have on motivation, wellbeing, and sense of accomplishment.

Component	Principle	Content	Actions
	purposeful activities builds psychosocial resources	Identify own psychosocial resources	Identifying a patient's own competencies and harness those to support recovery
		Motivation	Identifying those occupations that will serve as drivers during recovery
		Competence building	Selecting activities that match and appropriately challenge physiologic capabilities to build trust in using the affected limb, ensure success and lead to mastery
		Wellbeing, reclaiming normality, building optimism	Enabling those activities that are most likely to contribute to feelings of wellbeing and a sense of normality. Identifying practices which support wellbeing such as exercise, sleep, nutrition, and mindfulness.
In-clinic practice and collaboration	Patient/therapist collaboration ensures a match between therapeutic goals and activities	Identify purposeful activities and occupations that act as drivers of rehabilitation	Define the essential and enjoyed activities and occupations that will motivate people towards recovery
		Selection of activities that match therapeutic goals	Collaborate on selection of activities that target biomechanical and occupational goals e.g., activities that promote wrist extension
		Activity grading and adaptation	Teach how to grade activities up and down to increase or reduce the challenge to the wrist
		Building competence	Use activity kete[1] to build competence and reassurance on safety of activities
		Optimising movement opportunities	Use activity kete[1] to give feedback on performance to optimise use of purposeful activities in producing therapeutic movement
		Regular review of activity selection and performance	At each therapy session review the activities performed over the previous week/s and those for the upcoming week/s

Component	Principle	Content	Actions
Home-based selection and performance of purposeful activities	Activities are performed as therapy	Performing purposeful activities at regular intervals during waking hours	Patients to perform a range of gradable, progressible activities throughout the day that appropriately challenge movement, strength, and function Activity selection is based on the education and in-clinic collaborations as above
			At-home activity selection will also be based on the adaptive cycle of activity selection and performance (Figure 32). This provides a framework for monitoring the response of the healing tissues to selected activities Analysing: is the activity suitable? Testing: tentative performance of the activity Doing: performing the activity Reflecting: does it hurt, is it too hard or sufficiently challenging? Recalibrate: make adaptations

[1] Kete. The Māori word for basket or kit. Māori language is used to reflect the unique context of Aotearoa, New Zealand, where the approach is situated.

11.4.3 Next steps required for development of an occupation-based rehabilitation approach

Table 24 provides an outline for elements to be included in an occupation-based rehabilitation approach. Bleijenberg et al. (2018) describes six steps to follow when developing a new approach or intervention. The initial three steps include identifying underpinning theoretical perspectives, an understanding of the existing evidence, and research to explain the causal mechanisms of an intervention. The research in my doctoral work explicitly addressed the steps of understanding the theory and evidence in Chapter 3 and in studies I and II. Primary research was undertaken in studies III and IV, to explain the rationale and mechanisms by which an occupation-based rehabilitative approach operates. The subsequent three steps described by (Bleijenberg et al., 2018) focus on transitioning the theoretical phase into clinical practice and testing. For the approach I am proposing the next step involves further development. This will require consultation with hand specialists to refine and confirm the framework for safe activity, an iterative refinement of therapist guidelines, detailing the approach according to the TIDieR guidelines (Hoffmann et al., 2014), and developing patient materials. Qualitative enquiry that seeks to understand clinician perspectives on occupation-based interventions is needed, particularly to identify any barriers that may prevent the uptake of such an approach. The next step involves trialling the approach in clinical practice to obtain feedback from patients and clinicians. Subsequently, a feasibility trial should be conducted to define appropriate outcome measures, test recruitment and retention procedures, and obtain estimates of effect sizes to inform sample size calculation for a randomised controlled study. The feasibility study should include a qualitative component to explore acceptability of the intervention to participants. Finally, investigating the approach through an appropropriately powered randomised controlled study, should be undertaken.

11.5 Limitations

Limitations of the individual studies are discussed within each manuscript: study I on page 60, study II in 5.2.5, study III on page 138, and study IV on page 183.

One limitation of this research is that I did not directly explore the perspectives of clinicians on the acceptability or willingness to adopt an occupationally-based approach. The perspectives of hand therapists and surgeons is needed to ensure that any perceived barriers are addressed and mitigated during intervention development. Another limitation is that measurement of wrist movement was conducted during a single session of 10-minutes. This means that the ranges and amounts of movement during waking hours are unknown. Also, the research is limited in its ability to determine how movement produced by purposeful activity varies at different time points following surgery. Another limitation of the research is that data collection occurred when participants were between four and eight weeks postoperatively. The influence of activity performance on recovery in the earliest stages of rehabilitation (from around 10 days to 3-4 weeks) was partly explored in study III but was not objectively measured in study IV. This was because the feasibility of conducting motion analysis on patients during very early bone healing was unknown when the study was designed.

11.6 Conclusions

This thesis explored how activity and occupation influences recovery from a surgically repaired distal radius fracture. Studies I and II were undertaken to investigate aspects of the literature on how activity and occupation influences recovery from surgical treatment of a distal radius fracture. Study I reviewed research which compared movement during purposeful and non-purposeful activity showing that in healthy people, movement was generally more efficient, performed for longer durations and with more repetitions during purposeful activity. Study II reviewed clinical research describing the activity in early postoperative rehabilitation. The results demonstrated that activity is safe and commonly recommended as part of early mobilisation recommendations, but poorly specified. These reviews identified the safety and potential of purposeful activity but highlighted that little is known about how they should be prescribed or their mechanisms of action.

My thesis then transitioned to primary research. First, I conducted an Interpretive Description qualitative investigation that explored patient perspectives and experiences of early recovery. The study showed that purposeful activity is highly valued for its ability to induce change in wrist movement and function and build psychosocial competencies. I then conducted a motion analysis study that compared wrist and forearm movement during purposeful activity and ROM exercises using a randomised crossover design, in adults with a surgically treated distal radius fracture. That study found evidence that activity produces movement that is more continuous, repetitious, and variable than exercise routines. The study provided evidence that purposeful activity has the potential to elicit therapeutically beneficial movement and may support early recovery of movement and function. In chapter 10 I highlighted specific characteristics of occupation in the production of movement and described the process by which people determine activity selection and performance.

Taken collectively, my research elucidates activity and occupation to be a complex, multi-dimensional therapeutic strategy that has potential beyond traditional models of postoperative care. I have reviewed studies that evidence the safety of purposeful activities and have provided preliminary evidence that people can make appropriate decisions about activities that safely challenge ROM and function. I have provided clear evidence that purposeful activity promotes substantial movement, and that occupation offers constantly recurring therapeutic opportunities. I have elucidated important knowledge that performing activities in the early postoperative period builds psychosocial resources that contribute to a positive rehabilitative experience and recovery. I proposed a rehabilitation approach that utilises the unique mechanisms and characteristics of occupation, more embedded in the everyday life demands of people, than a structured exercise regime. The approach offers a new horizon for postoperative rehabilitation that challenges traditional practice and could lead to substantial changes in the postoperative management of distal radius fractures.

References

Ackroyd, S., & Karlsson, J. C. (2014). Critical realism, research techniques, and research designs. In P. K. Edwards, J. O'Mahoney, & S. Vincent (Eds.), *Studying organizations using critical realism: A practical guide* (pp. 21-45). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199665525.003.0002

Adewuyi, A. A., Hargrove, L. J., & Kuiken, T. A. (2017). Resolving the effect of wrist position on myoelectric pattern recognition control. *Journal of Neuroengineering and Rehabilitation, 14*, 39. https://doi.org/10.1186/s12984-017-0246-x

Aizawa, J., Masuda, T., Koyama, T., Nakamaru, K., Isozaki, K., Okawa, A., & Morita, S. (2010). Three-dimensional motion of the upper extremity joints during various activities of daily living. *Journal of Biomechanics, 43*, 2915-2922. https://doi.org/10.1016/j.jbiomech.2010.07.006

Alluri, R., Longacre, M., Pannell, W., Stevanovic, M., & Ghiassi, A. (2015). Volar, intramedullary, and percutaneous fixation of distal radius fractures. *Journal of Wrist Surgery, 4*, 292-300. https://doi.org/10.1055/s-0035-1565926

Alter, T. H., Sandrowski, K., Gallant, G., Kwok, M., & Ilyas, A. M. (2018). Complications of volar plating of distal radius fractures: A systematic review. *Journal of Wrist Surgery*. https://doi.org/10.1055/s-0038-1667304

Álvarez, D., Alvarez, J. C., González, R. C., & López, A. M. (2016). Upper limb joint angle measurement in occupational health. *Computer Methods in Biomechanics and Biomedical Engineering, 19*, 159-170. https://doi.org/10.1080/10255842.2014.997718

American Occupational Therapy Association. (2020). Occupational therapy practice framework: Domain and process—fourth edition. *American Journal of Occupational Therapy, 74*(Suppl. 2), 1-87. https://doi.org/10.5014/ajot.2020.74S2001

Amini, D. A., Kannenberg, K., Bodison, S., Chang, P. F., Handley-More, D., McElroy, A., Colaianni, D., Goodrich, B., Mahaffey, L., Painter, M., Urban, M., Cooluris, K., & Lieberman, D. (2014). Occupational therapy practice framework: Domain & process 3rd edition. *American Journal of Occupational Therapy, 68*, S1-S48. https://doi.org/10.5014/ajot.2014.682006

Ammann, B., Satink, T., & Andresen, M. (2012). Experiencing occupations with chronic hand disability: Narratives of hand-injured adults. *Hand Therapy, 17*, 87-94. https://doi.org/10.1177/1758998312471253

Anderson, I., Crengle, S., Kamaka, M. L., Chen, T.-H., Palafox, N., & Jackson-Pulver, L. (2006). Indigenous health in australia, new zealand, and the pacific. *The Lancet, 367*, 1775-1785. https://doi.org/10.1016/S0140-6736(06)68773-4

Andrade-Silva, F. B., Rocha, J. P., Carvalho, A., Kojima, K. E., & Silva, J. S. (2018). Influence of postoperative immobilization on pain control of patients with distal radius fracture treated with volar locked plating: A prospective, randomized clinical trial. *Injury, 50*, 386-391. https://doi.org/10.1016/j.injury.2018.12.001

Andreasson, I., Kjellby-Wendt, G., Fagevik-Olsén, M., Karlsson, J., & Carlsson, G. (2020). Life has become troublesome – my wrist bothers me around the clock: An interview study relating to daily life with a malunited distal radius fracture. *Disability and Rehabilitation, 42*, 2344-2350. https://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=144871547&site=ehost-live&scope=site

Bailey, R. R., Klaesner, J. W., & Lang, C. E. (2014). An accelerometry-based methodology for assessment of real-world bilateral upper extremity activity. *PloS One, 9*, e103135. https://doi.org/10.1371/journal.pone.0103135

Bailey, R. R., Klaesner, J. W., & Lang, C. E. (2015). Quantifying real-world upper-limb activity in nondisabled adults and adults with chronic stroke. *Neurorehabilitation and neural repair, 29*, 969-978. https://doi.org/10.1177/1545968315583720

Bakshi, R., Bhambhani, Y., & Madill, H. (1991). The effects of task preference on performance during purposeful and nonpurposeful activities. *American Journal of Occupational Therapy, 45*, 912-916. https://doi.org/10.5014/ajot.45.10.912

Bamford, R., & Walker, D.-M. (2010). A qualitative investigation into the rehabilitation experience of patients following wrist fracture. *Hand Therapy, 15*, 54-61. https://doi.org/10.1258/ht.2010.010013

Barolia, R. I., Clark, A. M., & Higginbottom, G. M. (2013). Protocol for a qualitative study on promoting dietary change and positive food choices for poor people with low income who experience cardiovascular disease in pakistan. *BMJ Open, 3*, e004176. https://doi.org/10.1136/bmjopen-2013-004176

Bassett, S. F. (2003). The assessment of patient adherence to physiotherapy rehabilitation. *New Zealand Journal of Physiotherapy, 31*, 60-66. https://pnz.org.nz/

Bates, E., & Mason, R. (2014). Coping strategies used by people with a major hand injury: A review of the literature. *The British Journal of Occupational Therapy, 77*, 289-295. https://doi.org/10.4276/030802214X14018723137995

Bentohami, A., Bosma, J., Akkersdijk, G., Van Dijkman, B., Goslings, J., & Schep, N. (2014). Incidence and characteristics of distal radial fractures in an urban population in the netherlands. *European Journal of Trauma and Emergency Surgery, 40*, 357-361. https://doi.org/10.1007/s00068-014-0394-7

Berlet, L., & Kaskutas, V. (2020). Developing occupation kits in a hand therapy student experiential learning clinic. *Hand Therapy, 25*, 73-82. https://doi.org/10.1177/1758998320912680

Bialocerkowski, A. E. (2002). Difficulties associated with wrist disorders-a qualitative study. *Clinical Rehabilitation, 16*, 429-440. https://doi.org/10.1191/0269215502cr516oa

Bialocerkowski, A. E., & Grimmer, K. A. (2004). Compensatory mechanism use during the first 6 months following distal radius fracture. *International Journal of Therapy and Rehabilitation, 11*, 467-475. https://doi.org/10.12968/ijtr.2004.11.10.17191

Bialocerkowski, A. E., Grimmer, K. A., & Bain, G. I. (2003). Validity of the patient-focused wrist outcome instrument: Do impairments represent functional ability? *Hand Clinics, 19*, 449-455. https://doi.org/10.1016/S0749-0712(02)00148-8

Bigelius, U., Eklund, M., & Erlandsson, L.-K. (2010). The value and meaning of an instrumental occupation performed in a clinical setting. *Scandinavian Journal of Occupational Therapy, 17*, 4-9. https://doi.org/10.3109/11038120802714880

Biometrics Ltd. (2020). *Datalite wireless sensors operating manual software version 10 & version 11*. B. Ltd. www.biometricsltd.com

Björk, M., Niklasson, J., Westerdahl, E., & Sagerfors, M. (2020). Self-efficacy corresponds to wrist function after combined plating of distal radius fractures.

Journal of Hand Therapy, 33, 314-319. https://doi.org/10.1016/j.jht.2020.01.001

Bleijenberg, N., Janneke, M., Trappenburg, J. C., Ettema, R. G., Sino, C. G., Heim, N., Hafsteindóttir, T. B., Richards, D. A., & Schuurmans, M. J. (2018). Increasing value and reducing waste by optimizing the development of complex interventions: Enriching the development phase of the medical research council (MRC) framework. *International Journal of Nursing Studies, 79*, 86-93. https://doi.org/10.1016/j.ijnurstu.2017.12.001

Boudreau, S. A., Farina, D., & Falla, D. (2010). The role of motor learning and neuroplasticity in designing rehabilitation approaches for musculoskeletal pain disorders. *Manual Therapy, 15*, 410-414. https://doi.org/10.1016/j.math.2010.05.008

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*, 77-101. https://doi.org/10.1191/1478088706qp063oa

Braun, V., Clarke, V., Hayfield, N., & Terry, G. (2019). Thematic analysis. In P. Liamputtong (Ed.), *Handbook of research methods in health social sciences*. Springer https://doi.org/10.1007/978-981-10-5251-4_103

Brehmer, J. L., & Husband, J. B. (2014). Accelerated rehabilitation compared with a standard protocol after distal radial fractures treated with volar open reduction and internal fixation: A prospective, randomized, controlled study. *Journal of Bone and Joint Surgery (American Volume), 96*, 1621-1630. https://doi.org/10.2106/JBJS.M.00860

Brigstocke, G., Hearnden, A., Holt, C., & Whatling, G. (2014). In-vivo confirmation of the use of the dart thrower’s motion during activities of daily living. *Journal of Hand Surgery (European Volume), 39*, 373-378. https://doi.org/10.1177/1753193412460149

Brody, L. T. (2012). Effective therapeutic exercise prescription: The right exercise at the right dose. *Journal of Hand Therapy, 25*, 220-232. https://doi.org/10.1016/j.jht.2011.09.009

Brogren, E., Petranek, M., & Atroshi, I. (2007). Incidence and characteristics of distal radius fractures in a southern swedish region. *BMC Musculoskeletal Disorders, 8*, 48. https://doi.org/10.1186/1471-2474-8-48

Bruder, A. M., McClelland, J. A., Shields, N., Dodd, K. J., Hau, R., van de Water, A. T. M., & Taylor, N. F. (2018). Validity and reliability of an activity monitor to quantify arm movements and activity in adults following distal radius fracture. *Disability and Rehabilitation, 40*, 1318-1325. https://doi.org/10.1080/09638288.2017.1288764

Bruder, A. M., Shields, N., Dodd, K. J., & Taylor, N. F. (2017). Prescribed exercise programs may not be effective in reducing impairments and improving activity during upper limb fracture rehabilitation: A systematic review. *Journal of Physiotherapy, 63*, 205-220. https://doi.org/10.1016/j.jphys.2017.08.009

Bruder, A. M., Taylor, N. F., Dodd, K. J., & Shields, N. (2013). Physiotherapy intervention practice patterns used in rehabilitation after distal radial fracture. *Physiotherapy, 99*, 233-240. https://doi.org/10.1016/j.physio.2012.09.003

Burdon, C., Spronk, I., Cheng, H. L., & O'Connor, H. (2017). Effect of glycemic index of a pre-exercise meal on endurance exercise performance: A systematic review and meta-analysis. *Sports Medicine, 47*, 1087-1101. https://doi.org/10.1007/s40279-016-0632-8

Carr, A., Cullen, K., Keeney, C., Canning, C., Mooney, O., Chinseallaigh, E., & O'Dowd, A. (2020). Effectiveness of positive psychology interventions: A systematic review and meta-analysis. *The Journal of Positive Psychology*, 1-21. https://doi.org/10.1080/17439760.2020.1818807

Chan, A.-W., Tetzlaff, J. M., Altman, D. G., Laupacis, A., Gøtzsche, P. C., Krleža-Jerić, K., Hróbjartsson, A., Mann, H., Dickersin, K., & Berlin, J. A. (2013). Spirit 2013 statement: Defining standard protocol items for clinical trials. *Annals of Internal Medicine, 158*, 200-207. https://doi.org/10.7326/0003-4819-158-3-201302050-00583

Chan, J., & Spencer, J. (2004). Adaptation to hand injury: An evolving experience. *American Journal of Occupational Therapy, 58*, 128-139. https://doi.org/10.5014/ajot.58.2.128

Cherubino, P., Bini, A., & Marcolli, D. (2010). Management of distal radius fractures: Treatment protocol and functional results. *Injury, 41*, 1120-1126. https://doi.org/10.1016/j.injury.2010.09.016

Chudyk, A. M., Jutai, J. W., Petrella, R. J., & Speechley, M. (2009). Systematic review of hip fracture rehabilitation practices in the elderly. *Archives of Physical Medicine and Rehabilitation, 90*, 246-262. https://doi.org/10.1016/j.apmr.2008.06.036

Chung, K. C., & Haas, A. (2009). Relationship between patient satisfaction and objective functional outcome after surgical treatment for distal radius fractures. *Journal of Hand Therapy, 22*, 302-308. https://doi.org/10.1016/j.jht.2009.04.007

Chung, K. C., Kotsis, S. V., & Kim, H. M. (2007). Predictors of functional outcomes after surgical treatment of distal radius fractures. *Journal of Hand Surgery, 32*, 76-83. https://doi.org/10.1016/j.jhsa.2006.10.010

Chung, K. C., Malay, S., & Shauver, M. J. (2019). The relationship between hand therapy and long-term outcomes after distal radius fracture in older adults: Evidence from the randomized wrist and radius injury surgical trial. *Plastic and Reconstructive Surgery, 144*, 230e-237e. https://doi.org/10.1097/PRS.0000000000005829

Chung, K. C., Petruska, E. A., Chung, K. C., & Petruska, E. A. (2007). Treatment of unstable distal radial fractures with the volar locking plating system. Surgical technique. *Journal of Bone and Joint Surgery, 89*, 256-266. https://doi.org/10.2106/jbjs.g.00283

Chung, K. C., Sasor, S. E., Speth, K. A., Wang, L., & Shauver, M. J. (2020). Patient satisfaction after treatment of distal radial fractures in older adults. *The Journal of Hand Surgery, European volume, 45*, 77-84. https://doi.org/10.1177/1753193419878981

Claydon, J., Robinson, L., & Aldridge, S. (2017). Patients' perceptions of repair, rehabilitation and recovery after major orthopaedic trauma: A qualitative study. *Physiotherapy, 103*, 322-329. https://doi.org/10.1016/j.physio.2015.11.002

Clementsen, S. Ø., Hammer, O.-L., Šaltytė Benth, J., Jakobsen, R. B., & Randsborg, P.-H. (2019). Early mobilization and physiotherapy vs. Late mobilization and home exercises after orif of distal radial fractures: A randomized controlled trial. *JB & JS open access, 4*, 1-11. https://doi.org/10.2106/JBJS.OA.19.00012

Clemson, L., Singh, M. F., Bundy, A., Cumming, R. G., Weissel, E., Munro, J., Manollaras, K., & Black, D. (2010). Life pilot study: A randomised trial of balance and strength training embedded in daily life activity to reduce falls in older adults. *Australian Occupational Therapy Journal, 57*, 42-50. https://doi.org/10.1111/j.1440-1630.2009.00848.x

Colaianni, D., & Provident, I. (2010, Apr). The benefits of and challenges to the use of occupation in hand therapy. *Occupational Therapy in Health Care, 24*, 130-146. https://doi.org/10.3109/07380570903349378

Collis, J. M. (2014). *Revised hand therapy guideline for dupuytren's contracture - a prospective evaluation* [Poster]. NZ Society for Surgery of the Hand, Queenstown, New Zealand.

Collis, J. M. (2018). *Outcomes following silastic mcpj arthroplasty treated postoperatively in a dynamic splint* [Paper]. NZ Society for Surgery of the Hand, Queenstown, New Zealand.

Collis, J. M., & Collocott, S. (2009). *Dupuytren's contracture release: An audit of hand therapy outcomes at counties Manukau District Health Board* [Poster]. New Zealand Association of Hand Therapists Annual Conference, Tauranga, New Zealand.

Collis, J. M., Collocott, S., Hing, W., & Kelly, E. (2013). The effect of night extension orthoses following surgical release of dupuytren contracture: A single-center, randomized, controlled trial. *The Journal of Hand Surgery, 38*, 1285-1294.e1282. https://doi.org/10.1016/j.jhsa.2013.04.012

Collis, J. M., Mayland, E. C., Wright-St Clair, V., & Signal, N. (2021). “The more I do, the more I can do”: Perspectives on how performing daily activities and occupations influences recovery after surgical repair of a distal radius fracture. *Disability and Rehabilitation*(June 10), 1-10. https://doi.org/10.1080/09638288.2021.1936219

Collis, J. M., Signal, N., Mayland, E., & Wright-St Clair, V. (2020a). A systematic review of how daily activities and exercises are recommended following volar plating of distal radius fractures and the efficacy and safety of early versus late mobilisation. *Hand Therapy, 25*, 139-151. https://doi.org/10.1177/1758998320967032

Collis, J. M., Signal, N., Mayland, E., & Wright-St Clair, V. A. (2020b). Influence of purposeful activities on upper extremity motor performance: A systematic review. *OTJR: Occupation, Participation and Health, 40*, 223-234. https://doi.org/10.1177/1539449220912187

Cooper, E. O., Segalman, K. A., Parks, B. G., Sharma, K. M., & Nguyen, A. (2007). Biomechanical stability of a volar locking-screw plate versus fragment-specific fixation in a distal radius fracture model. *American Journal of Orthopedics, 32*, E46-E49.

Cooper, H., Hedges, L., & Valentine, J. (Eds.). (2019). *The handbook of research synthesis and meta-analysis* (3rd ed.). Russell Sage Foundation. https://doi.org/10.7758/9781610448864.14

Coury, H. J. C. G., Alfredo Léo, J., & Kumar, S. (2000). Effects of progressive levels of industrial automation on force and repetitive movements of the wrist. *International Journal of Industrial Ergonomics, 25*, 587-595. https://doi.org/10.1016/S0169-8141(99)00045-1

Crabtree, J. L. (2010). No one dresses accidentally: A research synthesis on intentional occupational performance. *OTJR: Occupation, Participation and Health, 30*, 100-110. https://doi.org/10.3928/15394492-20090725-01

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2013). Developing and evaluating complex interventions: The new medical research council guidance. *International Journal of Nursing Studies, 50*, 587-592. https://doi.org/10.1016/j.ijnurstu.2012.09.010

Creswell, J. W., & Creswell, J. D. (2018). The selection of a research approach. In *Research design : Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage.

Creswell, J. W., & Plano Clark, V. L. (2017). The foundations of mixed methods research. In *Designing and conducting mixed methods research* (3rd ed.). Sage publications.

Cruickshank, J. (2012). Positioning positivism, critical realism and social constructionism in the health sciences: A philosophical orientation. *Nursing Inquiry, 19*, 71-82. https://doi.org/10.1111/j.1440-1800.2011.00558.x

da Silva Camassuti, P. A., Marcolino, A. M., Tamanini, G., Barbosa, R. I., Barbosa, A. M., & de Cássia Registro Fonseca, M. (2015). Inter-rater, intra-rater and inter-instrument reliability of an electrogoniometer to measure wrist range of motion. *Hand Therapy, 20*, 3-10. https://doi.org/10.1177/1758998315570681

Dahl, W. J., Nassab, P. F., Burgess, K. M., Postak, P. D., Evans, P. J., Seitz, W. H., Greenwald, A. S., & Lawton, J. N. (2012). Biomechanical properties of fixed-angle volar distal radius plates under dynamic loading. *Journal of Hand Surgery, 37*, 1381-1387. https://doi.org/10.1016/j.jhsa.2012.03.021

Daud, A. Z. C., Judd, J., Yau, M., & Barnett, F. (2016a). Barriers of occupation-based intervention. *Asian Journal of Quality of Life, 1*, 1-10. https://doi.org/10.21834/ajqol.v1i4.12

Daud, A. Z. C., Judd, J., Yau, M., & Barnett, F. (2016b). Issue in applying occupation-based intervention in clinical practice: A delphi study. *Procedia-Social and Behavioral Sciences, 222*, 272-282. https://doi.org/10.1016/j.sbspro.2016.05.158

Daud, A. Z. C., Yau, M. K., Barnett, F., & Judd, J. (2016). Occupation-based intervention in hand injury rehabilitation: Experiences of occupational therapists in malaysia. *Scandinavian Journal of Occupational Therapy, 23*, 57-66. https://doi.org/10.3109/11038128.2015.1062047

Daud, A. Z. C., Yau, M. K., Barnett, F., Judd, J., Jones, R. E., & Muhammad Nawawi, R. F. (2016). Integration of occupation based intervention in hand injury rehabilitation: A randomized controlled trial. *Journal of Hand Therapy, 29*, 30-40. https://doi.org/10.1016/j.jht.2015.09.004

de los Reyes-Guzmán, A., Gil-Agudo, A., Peñasco-Martín, B., Solís-Mozos, M., del Ama-Espinosa, A., & Pérez-Rizo, E. (2010). Kinematic analysis of the daily activity of drinking from a glass in a population with cervical spinal cord injury. *Journal of Neuroengineering and Rehabilitation, 7*, 41. https://doi.org/10.1186/1743-0003-7-41

de Vreede, P. L., Samson, M. M., Van Meeteren, N. L., Van Der Bom, J. G., Duursma, S. A., & Verhaar, H. J. (2004). Functional tasks exercise versus resistance exercise to improve daily function in older women: A feasibility study. *Archives of Physical Medicine and Rehabilitation, 85*, 1952-1961. https://doi.org/10.1016/j.apmr.2004.05.006

Dekkers, M., & Soballe, K. (2004). Activities and impairments in the early stage of rehabilitation after colles' fracture. *Disability and Rehabilitation, 26*(11), 662-668. https://doi.org/10.1080/09638280410001683173

den Hollander, M., Goossens, M., de Jong, J., Ruijgrok, J., Oosterhof, J., Onghena, P., Smeets, R., & Vlaeyen, J. W. S. (2016). Expose or protect? A randomized controlled trial of exposure in vivo vs pain-contingent treatment as usual in patients with complex regional pain syndrome type 1. *Pain, 157*, 2318-2329. https://doi.org/10.1097/j.pain.0000000000000651

Dennison, D. G., Blanchard, C. L., Elhassan, B., Moran, S. L., & Shin, A. Y. (2020). Early versus late motion following volar plating of distal radius fractures. *Hand, 15*, 125-130. https://doi.org/10.1177/1558944718787880

Dewan, N., MacDermid, J. C., Grewal, R., & Beattie, K. (2017). Recovery patterns over 4 years after distal radius fracture: Descriptive changes in fracture-specific pain/disability, fall risk factors, bone mineral density, and general health status. *Journal of Hand Therapy*. https://doi.org/10.1016/j.jht.2017.06.009

Dewan, N., MacDermid, J. C., & Packham, T. (2013). Role of a self-efficacy-based model of intervention: The learn approach in rehabilitation of distal radius fracture. *Critical Reviews in Physical and Rehabilitation Medicine, 25*, 241-259. https://doi.org/10.1615/critrevphysrehabilmed.2013010110

Dobkin, B. H. (2013). Wearable motion sensors to continuously measure real-world physical activities. *Current Opinion in Neurology, 26*(6), 602-608. https://doi.org/10.1097/WCO.0000000000000026

Downs, S. H., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *Journal of Epidemiology and Community Health, 52*, 377-384. https://doi.org/10.1136/jech.52.6.377

Drobetz, H., Koval, L., Weninger, P., Luscombe, R., Jeffries, P., Ehrendorfer, S., & Heal, C. (2016). Volar locking distal radius plates show better short-term results than other treatment options: A prospective randomised controlled trial. *World Journal Of Orthopedics, 7*, 687-694. https://doi.org/10.5312/wjo.v7.i10.687

Duncan, E. A., & Nicol, M. M. (2004). Subtle realism and occupational therapy: An alternative approach to knowledge generation and evaluation. *British Journal of Occupational Therapy, 67*(10), 453-456. https://doi.org/10.1177/030802260406701006

Duprat, A., Diaz, J. J. H., Vernet, P., Gouzou, S., Facca, S., Igeta, Y., & Liverneaux, P. (2018). Volar locking plate fixation of distal radius fractures: Splint versus immediate mobilization. *Journal of Wrist Surgery, 7*, 237-242. https://doi.org/10.1055/s-0037-1620271

Dwan, K., Li, T., Altman, D. G., & Elbourne, D. (2019). Consort 2010 statement: Extension to randomised crossover trials. *BMJ, 366*, 1-16. https://doi.org/10.1136/bmj.l4378

Dy, L. B., & Yancosek, K. E. (2017). Introducing purposeful activity kits in a hand rehabilitation practice: Effects on clinical practice patterns and job satisfaction among occupational therapy practitioners. *Hand Therapy, 22*, 3-12. https://doi.org/10.1177/1758998316657844

Eakman, A., Carlson, M., & Clark, F. (2010). The meaningful activity participation assessment: A measure of engagement in personally valued activities. *International Journal of Aging and Human Development, 70*, 299-317. https://doi.org/10.2190/ag.70.4.b

Egol, K. A., Karia, R., Zingman, A., Lee, S., & Paksima, N. (2014). Hand stiffness following distal radius fractures: Who gets it and is it a functional problem? *Bulletin of the Hospital for Joint Diseases, 72*, 288-293. https://doi.org/10.1016/s0363-5023(09)60100-3

Eklund, M., Erlandsson, L.-K., Persson, D., & Hagell, P. (2009). Rasch analysis of an instrument for measuring occupational value: Implications for theory and practice. *Scandinavian Journal of Occupational Therapy, 16*, 118-128. https://doi.org/10.1080/11038120802596253

Elliott, M. T., Karim, D., Clark, T., Masood, A., Kearney, R., & Metcalfe, A. (2017). *Feasibility of using the leap motion hand gesture sensor for tracking wrist fracture physiotherapy* WIN Annual Conference,

Fantozzi, S., Giovanardi, A., Magalhães, F. A., Di Michele, R., Cortesi, M., & Gatta, G. (2016). Assessment of three-dimensional joint kinematics of the upper limb during simulated swimming using wearable inertial-magnetic measurement units. *Journal of Sports Sciences, 34*, 1073-1080. https://doi.org/10.1080/02640414.2015.1088659

Fasoli, S. E., Trombly, C. A., Tickle-Degnen, L., & Verfaellie, M. H. (2002). Context and goal-directed movement: The effect of materials-based occupation. *OTJR Occupation, Participation and Health, 22*, 119-128. https://doi.org/10.1177/153944920202200305

Fernandez, D. (2001). Distal radius fracture: The rationale of a classification. *Chirurgie de la Main, 20*, 411-425. https://doi.org/10.1016/S1297-3203(01)00067-1

Fisher, A. G. (2014). Occupation-centred, occupation-based, occupation-focused: Same, same or different? *Scandinavian Journal of Occupational Therapy, 21* (Suppl 1), 96-107. https://doi.org/10.3109/11038128.2014.952912

Fletcher, A. J. (2017). Applying critical realism in qualitative research: Methodology meets method. *International Journal of Social Research Methodology, 20*, 181-194. https://doi.org/10.1080/13645579.2016.1144401

Foltran, F. A., Silva, L. C., Sato, T. O., & Coury, H. J. (2013). Wrist electrogoniometry: Are current mathematical correction procedures effective in reducing crosstalk in functional assessment? *Brazilian journal of physical therapy, 17*, 32-40. https://doi.org/10.1590/S1413-35552012005000067

Fowler, J. R., & Ilyas, A. M. (2013). Prospective evaluation of distal radius fractures treated with variable-angle volar locking plates. *Journal of Hand Surgery, 38*, 2198-2203. https://doi.org/10.1016/j.jhsa.2013.08.116

Frame, J. (1979). *Living in the maniototo*. George Braziller, Inc.

Fristedt, P. (2018). Relativism and the conversation of the world. *Philosophical Forum, 49*, 379-395. https://doi.org/10.1111/phil.12198

Gates, D. H., Walters, L. S., Cowley, J., Wilken, J. M., & Resnik, L. (2016). Range of motion requirements for upper-limb activities of daily living. *American Journal of Occupational Therapy, 70*, 1-12. https://doi.org/10.5014/ajot.2016.015487

Gentner, R., & Classen, J. (2009, Mar 30). Development and evaluation of a low-cost sensor glove for assessment of human finger movements in neurophysiological settings. *Journal of Neuroscience Methods, 178*, 138-147. https://doi.org/10.1016/j.jneumeth.2008.11.005

George, S. Z., Lentz, T. A., Zeppieri Jr, G., Lee, D., & Chmielewski, T. L. (2012). Analysis of shortened versions of the tampa scale for kinesiophobia and pain catastrophizing scale for patients following anterior cruciate ligament reconstruction. *The Clinical Journal of Pain, 28*, 73. https://doi.org/10.1097/AJP.0b013e31822363f4

Ghaddaf, A. A., Abdulhamid, A. S., Alomari, M. S., Alquhaibi, M. S., Alshehri, A. A., & Alshehri, M. S. (2021). Comparison of immobilization periods following open reduction and internal fixation of distal radius fracture: A systematic review and meta-analysis. *Journal of Hand Therapy*. https://doi.org/10.1016/j.jht.2021.06.004

Glasgow, C., Tooth, L. R., & Fleming, J. (2010). Mobilizing the stiff hand: Combining theory and evidence to improve clinical outcomes. *Journal of Hand Therapy, 23*, 392-401. https://doi.org/10.1016/j.jht.2010.05.005

Gong, H. S., Cho, H. E., Kim, J., Kim, M. B., Lee, Y. H., & Baek, G. H. (2015). Surgical treatment of acute distal radioulnar joint instability associated with distal radius fractures. *Journal of Hand Surgery, European Volume, 40*, 783-789. https://doi.org/10.1177/1753193415588478

Gracia-Ibáñez, V., Vergara, M., Sancho-Bru, J. L., Mora, M. C., & Piqueras, C. (2017). Functional range of motion of the hand joints in activities of the international classification of functioning, disability and health. *Journal of Hand Therapy, 30*, 337-347. https://doi.org/10.1016/j.jht.2016.08.001

Gray, J. M. (1998). Putting occupation into practice: Occupation as ends, occupation as means. *American Journal of Occupational Therapy, 52*, 354-364. https://doi.org/10.5014/ajot.52.5.354

Guitard, P., Brosseau, L., Wells, G. A., Paquet, N., Paterson, G., Toupin-April, K., Cavallo, S., Aydin, S. Z., Léonard, G., & De Angelis, G. (2018). The knitting community-based trial for older women with osteoarthritis of the hands: Design and rationale of a randomized controlled trial. *BMC Musculoskeletal Disorders, 19*, 1-11. https://doi.org/10.1186/s12891-018-1965-2

Gupta, D. M., Boland, R. J., & Aron, D. C. (2017). The physician's experience of changing clinical practice: A struggle to unlearn. *Implementation Science, 12*, 1-11. https://doi.org/10.1186/s13012-017-0555-2

Gutiérrez-Espinoza, H., Araya-Quintanilla, F., Olguín-Huerta, C., Gutiérrez-Monclus, R., Jorquera-Aguilera, R., & Mathoulin, C. (2021). Effectiveness of early versus delayed motion in patients with distal radius fracture treated with volar locking plate: A systematic review and meta-analysis. *Hand Surgery and Rehabilitation, 40*, 6-16. https://doi.org/10.1016/j.hansur.2020.10.007

Guzelkucuk, U., Duman, I., Taskaynatan, M. A., & Dincer, K. (2007). Comparison of therapeutic activities with therapeutic exercises in the rehabilitation of young adult patients with hand injuries. *Journal of Hand Surgery, 32*, 1429-1435. https://doi.org/10.1016/j.jhsa.2007.08.008

Hagert, E., Karagiannopoulos, C., & Rein, S. (2021). Proprioception in hand rehabilitation In T. M. Skirven, A. L. Osterman, J. Fedorczyk, P. C. Amadio, & E. K. S. Feldscher (Eds.), *Rehabilitation of the hand and upper extremity* (pp. 1393-1409). Elsevier Mosby.

Halcomb , E., & Hickman ,L. (2014). Mixed methods research. *Nursing Standard, 29*, 41-47. https://doi.org/10.7748/ns.29.32.41.e8858

Hall, B. A., & Nelson, D. L. (1998). The effect of materials on performance: A kinematic analysis of eating. *Scandinavian Journal of Occupational Therapy, 5*, 69-81. https://doi.org/10.3109/11038129809035732

Hall, J., Llewellyn, A., Palmer, S., Rowett-Harris, J., Atkins, R. M., & McCabe, C. S. (2016). Sensorimotor dysfunction after limb fracture–an exploratory study. *European Journal of Pain, 20*, 1402-1412. https://doi.org/10.1002/ejp.863

Hamasaki, T., Pelletier, R., Bourbonnais, D., Harris, P., & Choinière, M. (2018). Pain-related psychological issues in hand therapy. *Journal of Hand Therapy, 31*, 215-226. https://doi.org/10.1016/j.jht.2017.12.009

Hammell, K. W. (2010). Contesting assumptions in occupational therapy. In M. Curtin, M. Molineux, & J. Webb (Eds.), *Occupational therapy and physical dysfunction: Enabling occupation* (pp. 1-54). Elsevier.

Han, S.-H., Ryu, M.-H., & Kim, J.-N. (2018). Human joint angle estimation with multiple-strip e-textile stretching sensor. *Sensors and Materials, 30*(8), 1787-1793.

Handoll, H. H., & Elliott, J. (2015, Sep 25). Rehabilitation for distal radial fractures in adults. *Cochrane Database of Systematic Reviews, 9*, 1465-1858. https://doi.org/10.1002/14651858.CD003324.pub3

Hansen, A. Ø., Cederlund, R., Kristensen, H. K., & Tromborg, H. (2016). The effect of an occupation-based intervention in patients with hand-related disorders grouped using the sense of coherence scale: Study protocol. *Hand Therapy, 21*, 90-99. https://doi.org/10.1177/1758998316651456

Hansen, A. Ø., Kristensen, H. K., Cederlund, R., Möller, S., & Tromborg, H. (2020). An occupation-based intervention in patients with hand-related disorders grouped using the sense of coherence scale—a randomized controlled trial. *Journal of Hand Therapy, 33*, 455-469. https://doi.org/10.1016/j.jht.2019.12.009

Hansson, G.-Å., Balogh, I., Ohlsson, K., & Skerfving, S. (2004). Measurements of wrist and forearm positions and movements: Effect of, and compensation for, goniometer crosstalk. *Journal of Electromyography and Kinesiology, 14*, 355-367. https://doi.org/10.1016/j.jelekin.2003.10.001

Harris, J. E., MacDermid, J. C., & Roth, J. (2005). The international classification of functioning as an explanatory model of health after distal radius fracture: A cohort study. *Health and Quality of Life Outcomes, 3*, 73. https://doi.org/10.1186/1477-7525-3-73

Hawker, G. A., Mian, S., Kendzerska, T., & French, M. (2011). Measures of adult pain. *Arthritis Care & Research, 63*, S240-S252. https://doi.org/10.1002/acr.20543

Hays, P. L., & Rozental, T. D. (2013). Rehabilitative strategies following hand fractures. *Hand Clinics, 29*, 585-600. https://doi.org/10.1016/j.hcl.2013.08.011

Hayward, K. S., Eng, J. J., Boyd, L. A., Lakhani, B., Bernhardt, J., & Lang, C. E. (2016). Exploring the role of accelerometers in the measurement of real world upper-limb use after stroke. *Brain Impairment, 17*, 16-33. https://doi.org/10.1017/BrImp.2015.21

Heilskov-Hansen, T., Svendsen, S. W., Thomsen, J. F., Mikkelsen, S., & Hansson, G.-Å. (2014). Sex differences in task distribution and task exposures among danish house painters: An observational study combining questionnaire data with biomechanical measurements. *PloS One, 9*, e110899. https://doi.org/10.1371/journal.pone.0110899

Hétu, S., & Mercier, C. (2012). Using purposeful tasks to improve motor performance: Does object affordance matter? *British Journal of Occupational Therapy, 75*, 367-376. https://doi.org/10.4276/030802212X13433105374314

Hildebrand, M. W., Host, H. H., Binder, E. F., Carpenter, B., Freedland, K. E., Morrow-Howell, N., Baum, C. M., Doré, P., & Lenze, E. J. (2012). Measuring treatment fidelity in a rehabilitation intervention study. *American Journal of Physical Medicine and Rehabilitation, 91*, 715. https://doi.org/10.1097/phm.0b013e31824ad462

Hillstrom, H. J., Garg, R., Kraszewski, A., Lenhoff, M., Carter, T., Backus, S. I., Wolff, A., Syrkin, G., Cheng, R., & Wolfe, S. W. (2014). Development of an anatomical wrist joint coordinate system to quantify motion during functional tasks. *Journal of Applied Biomechanics, 30*, 586-593. https://doi.org/10.1123/jab.2011-0094

Hinojosa, J., & Blount, M. (2014a). Application of activities to enhance occupational performance. In J. Hinojosa & M. Blount (Eds.), *The texture of life: Occupations and related activities* (pp. 169-192). American Occupational Therapy Association, Inc.

Hinojosa, J., & Blount, M. (2014b). Occupation, activities, and occupational therapy. In J. Hinojosa & M. Blount (Eds.), *The texture of life: Occupations and related activities* (pp. 1-16). American Occupational Therapy Association, Inc.

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., Altman, D. G., Barbour, V., Macdonald, H., & Johnston, M. (2014). Better reporting of interventions: Template for intervention description and replication checklist and guide. *British Medical Journal, 348*, g1687 to g1687. https://doi.org/10.1136/bmj.g1687

Holubar, M. N., & Rice, M. S. (2006). The effects of contextual relevance and ownership on a reaching and placing task. *Australian Occupational Therapy Journal, 53*, 35-42. https://doi.org/10.1111/j.1440-1630.2006.00538.x

Hoppe, K. A., Miller, B. K., & Rice, M. S. (2008). Occupationally embedded exercise versus rote exercise and psychosocial response in college-aged females. *Occupational Therapy in Mental Health, 24*, 176-191. https://doi.org/10.1080/01642120802055317

Howick, J., Chalmers, I., Glasziou, T. G., Heneghan, C., Liberati, A., Moschetti, I., Phillips, B., Thornton, O. G., & Hodgkinson, M. (2011). *Explanation of the 2011 Oxford Centre for Evidence-Based Medicine (ocebm) levels of evidence (background document)*. Oxford Centre for Evidence-Based Medicine. https://www.cebm.net/index.aspx?o=5653

Huang, B., Li, M., Mei, T., McCoul, D., Qin, S., Zhao, Z., & Zhao, J. (2017). Wearable stretch sensors for motion measurement of the wrist joint based on dielectric elastomers. *Sensors (Basel), 17*, 1-12. https://doi.org/10.3390/s17122708

Hudson, M. L., & Russell, K. (2009). The Treaty of Waitangi and research ethics in Aotearoa. *Journal of Bioethical Inquiry*, 61-68. https://doi.org/10.1007/s11673-008-9127-0

Hughes, L. E., & Babski-Reeves, K. (2003). Evaluation of an electrogoniometer for wrist position measurements. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 47*, 1112-1116. https://doi.org/10.1177/154193120304701002

Hunt, M. R. (2009). Strengths and challenges in the use of interpretive description: Reflections arising from a study of the moral experience of health professionals in humanitarian work. *Qualitative Health Research, 19*, 1284-1292. https://doi.org/10.1177/1049732309344612

Iitsuka, T., Iwatsuki, K., Ota, H., & Hirata, H. (2016). The optimal rehabilitation period for patients with distal radius fractures according to the mcid in dash scores; a preliminary study. *The Journal of Hand Surgery Asian-Pacific volume, 21*, 161-166. https://doi.org/10.1142/S2424835516500144

Ikpeze, T. C., Smith, H. C., Lee, D. J., & Elfar, J. C. (2016). Distal radius fracture outcomes and rehabilitation. *Geriatric orthopaedic surgery & rehabilitation, 7*, 202-205. https://doi.org/10.1177/2151458516669202

Imai, R., Osumi, M., Ishigaki, T., & Morioka, S. (2018). Relationship between pain and hesitation during movement initiation after distal radius fracture surgery: A preliminary study. *Hand Surgery and Rehabilitation, 37*, 167-170. https://doi.org/10.1016/j.hansur.2018.02.003

Imai, R., Osumi, M., Ishigaki, T., & Morioka, S. (2020). Kinematic analyses using finger-tapping task for patients after surgery with distal radius fracture at acute phase. *Hand*. https://doi.org/10.1177/1558944720949952

IMeasureU. (2018). *Measure what matters*. Vicon. Retrieved January 23, 2019 from https://imeasureu.com/imu-sensor/

Inclan, P. M., & Dy, C. J. (2021). How to treat distal radius fractures right patient, right care, right time, and right cost. *Hand Clinics, 37*, 205-214. https://doi.org/10.1016/j.hcl.2021.02.003

Javed, S., Shahid, R., Thimmiah, R., & El-deen, M. (2015). Volar locking plate osteosynthesis for distal radial fractures. *Journal of Orthopaedic Surgery (Hong Kong), 23*, 323-326. https://doi.org/10.1177/230949901502300313

Jayakumar, P., Teunis, T., Vranceanu, A. M., Williams, M., Lamb, S., Ring, D., & Gwilym, S. (2020). The impact of a patient's engagement in their health on the magnitude of limitations and experience following upper limb fractures. *The Bone & Joint Journal, 102*, 42-47. https://doi.org/10.1302/0301-620X.102B1. BJJ-2019-0421.R1

Johnson, P. W., Jonsson, P., & Hagberg, M. (2002). Comparison of measurement accuracy between two wrist goniometer systems during pronation and supination. *Journal of Electromyography and Kinesiology, 12*, 413-420. https://doi.org/https://doi.org/10.1016/S1050-6411(02)00031-7

Kamei, S., Osada, D., Tamai, K., Kato, N., Takai, M., Kameda, M., & Nohara, Y. (2010). Stability of volar locking plate systems for ao type c3 fractures of the distal radius: Biomechanical study in a cadaveric model. *Journal Of Orthopaedic Science: Official Journal Of The Japanese Orthopaedic Association, 15*, 357-364. https://doi.org/10.1007/s00776-010-1466-0

Karagiannopoulos, C., & Michlovitz, S. (2016). Rehabilitation strategies for wrist sensorimotor control impairment: From theory to practice. *Journal of Hand Therapy, 29*, 154-165. https://doi.org/10.1016/j.jht.2015.12.003

Karagiannopoulos, C., Sitler, M., Michlovitz, S., & Tierney, R. (2013). A descriptive study on wrist and hand sensori-motor impairment and function following distal radius fracture intervention. *Journal of Hand Therapy, 26*, 204-215. https://doi.org/10.1016/j.jht.2013.03.004

Karl, J. W., Olson, P. R., & Rosenwasser, M. P. (2015). The epidemiology of upper extremity fractures in the united states, 2009. *Journal of Orthopaedic Trauma, 29*, e242-e244. https://doi.org/10.1097/bot.0000000000000312

Karnezis, I. A., & Fragkiadakis, E. G. (2002). Association between objective clinical variables and patient-rated disability of the wrist. *The Journal of Bone and Joint Surgery. British volume, 84*, 967-970. https://doi.org/10.1302/0301-620x.84b7.0840967

Kasten, P., Rettig, O., Loew, M., Wolf, S., & Raiss, P. (2009). Three-dimensional motion analysis of compensatory movements in patients with radioulnar synostosis performing activities of daily living. *Journal of Orthopaedic Science, 14*, 307-312.

Kehoe, R., & Rice, M. S. (2016). Reality, virtual reality, and imagery: Quality of movement in novice dart players. *British Journal of Occupational Therapy, 79*, 244-251. https://doi.org/10.1177/0308022615616820

Keizer, J., Roukema, G. R., Rhemrev, S. J., & Meylaerts, S. A. (2013). Volar plating for displaced intraarticular fractures of the distal radius in an elderly population. *Current Orthopaedic Practice, 24*, 298-303. https://doi.org/10.1097/BCO.0b013e31828df546

Kim, S.-J., Jo, Y.-H., Choi, W.-S., Lee, C.-H., Lee, B.-G., Kim, J.-H., & Lee, K.-H. (2017). Biomechanical properties of 3-dimensional printed volar locking distal radius plate: Comparison with conventional volar locking plate. *Journal of Hand Surgery, 42*, 747. https://doi.org/10.1016/j.jhsa.2017.05.009

Kim, T. S., Park, D. D. H., Lee, Y. B., Han, D. G., su Shim, J., Lee, Y. J., & Kim, P. C. W. (2014). A study on the measurement of wrist motion range using the iphone 4 gyroscope application. *Annals of Plastic Surgery, 73*, 215-218. https://doi.org/10.1097/SAP.0b013e31826eabfe

King, T. I. (1993). Hand strengthening with a computer for purposeful activity. *American Journal of Occupational Therapy, 47*, 635-637. https://doi.org/10.5014/ajot.47.7.635

Kingston, G. A., Judd, J., & Gray, M. A. (2014). The experience of living with a traumatic hand injury in a rural and remote location: An interpretive phenomenological study. *Rural and Remote Health, 14*, 1-12.

Kirby, E., & Sparrow, S. (2017). A retrospective analysis of the number of therapy visits after distal radius fractures using a new provider-scored clinical severity scale. *Journal of Hand Therapy*. https://doi.org/10.1016/j.jht.2017.06.008

Kleim, J. A., & Jones, T. A. (2008). Principles of experience-dependent neural plasticity: Implications for rehabilitation after brain damage. *Journal of Speech, Language & Hearing Research, 51*, S225-S239. https://doi.org/10.1044/1092-4388(2008/018)

Klein, S., Prantl, L., Koller, M., Vykoukal, J., Dolderer, J., Graf, S., Nerlich, M., Loibl, M., & Geis, S. (2015). Evidence based postoperative treatment of distal radius fractures following internal locking plate fixation. *Acta Chirurgiae Orthopaedicae et Traumatologiae Cechoslovaca, 82*, 33-40.

Koh, S., Morris, R. P., Patterson, R. M., Kearney, J. P., Buford, W. L., Jr., & Viegas, S. F. (2006). Volar fixation for dorsally angulated extra-articular fractures of the distal radius: A biomechanical study. *Journal of Hand Surgery, 31*, 771-779. https://doi.org/10.1016/j.jhsa.2006.02.015

Kong, L., Zhai, Y., Zhang, Z., Lu, J., Zhang, B., & Tian, D. (2020). Radiocarpal joint stiffness following surgical treatment for distal radius fractures: The incidence and associated factors. *Journal of Orthopaedic Surgery and Research, 15*(1), 313. https://doi.org/10.1186/s13018-020-01857-6

Kontaxis, A., Cutti, A. G., Johnson, G. R., & Veeger, H. (2009). A framework for the definition of standardized protocols for measuring upper-extremity kinematics. *Clinical Biomechanics, 24*(3), 246-253. https://doi.org/10.1016/j.clinbiomech.2008.12.009

Koo, O. T., Tan, D. M., & Chong, A. K. (2013, Aug). Distal radius fractures: An epidemiological review. *Orthopaedic Surgery, 5*, 209-213. https://doi.org/10.1111/os.12045

Kooner, P., & Grewal, R. (2021). Is therapy needed after distal radius fracture treatment, what is the evidence? *Hand Clinics, 37*, 309-314. https://doi.org/10.1016/j.hcl.2021.02.012

Kramer, P., & Hinojosa, J. (2014). Activity synthesis as a means to structure occupation. In J. Hinojosa & M.-L. Blount (Eds.), *The texture of life: Occupations and related activities* (4th ed., pp. 121-140). American Occupational Therapy Association, Inc.

Krischak, G. D., Krasteva, A., Schneider, F., Gulkin, D., Gebhard, F., & Kramer, M. (2009). Physiotherapy after volar plating of wrist fractures is effective using a home exercise program. *Archives of Physical Medicine and Rehabilitation, 90*, 537-544. https://doi.org/10.1016/j.apmr.2008.09.575

Kumar, Y., Yen, S.-C., Tay, A., Lee, W., Gao, F., Zhao, Z., Li, J., Hon, B., Xu, T. T.-M., & Cheong, A. (2015). Wireless wearable range-of-motion sensor system for upper and lower extremity joints: A validation study. *Healthcare technology letters, 2*, 12-17. https://doi.org/10.1049/htl.2014.0100

Kwan, K., Lau, T. W., & Leung, F. (2011). Operative treatment of distal radial fractures with locking plate system - a prospective study. *International Orthopaedics, 35*, 389-394. https://doi.org/http://dx.doi.org/10.1007/s00264-010-0974-z

Labes, D. (2019). *Randomizebe: Create a random list for crossover studies. R package.* Retrieved October 19, 2020 from https://cran.r-project.org/web/packages/randomizeBE

Lalone, E., MacDermid, J. C., Grewal, R., & King, G. (2017). Patient reported pain and disability following a distal radius fracture: A prospective study. *The Open Orthopaedics Journal, 11*, 589-599. https://doi.org/10.2174/1874325001711010589

Lang, C. E., Waddell, K. J., Klaesner, J. W., & Bland, M. D. (2017). A method for quantifying upper limb performance in daily life using accelerometers. *Journal of Visualized Experiments, 122*, e55673. https://doi.org/10.3791/55673

Larsson, C., Hansson, E. E., Sundquist, K., & Jakobsson, U. (2016). Kinesiophobia and its relation to pain characteristics and cognitive affective variables in older adults with chronic pain. *BMC Geriatrics, 16*, 128. https://doi.org/10.1186/s12877-016-0302-6

LaStayo, P. C., & Wheeler, D. L. (1994). Reliability of passive wrist flexion and extension goniometric measurements: A multicenter study. *Physical Therapy, 74*, 162-174. https://doi.org/10.1093/PTJ/74.2.162

Latz, D., Schiffner, E., Schneppendahl, J., Hilsmann, F., Seiler, L. F., Jungbluth, P., Kaufmann, R. A., Windolf, J., & Gehrmann, S. V. (2019). Doctor, when can I drive?—the range of elbow motion while driving a car. *Journal of Shoulder and Elbow Surgery, 28*, 1139-1145. https://doi.org/10.1016/j.jse.2018.11.053

Law, M. (2002). Participation in the occupations of everyday life. *American Journal of Occupational Therapy, 56*, 640-649. https://doi.org/10.5014/ajot.56.6.640

Lawinger, E., Uhl, T. L., Abel, M., & Kamineni, S. (2015). Assessment of accelerometers for measuring upper-extremity physical activity. *Journal of Sport Rehabilitation, 24*, 236-243. https://doi.org/10-1123/jsr.2013-0140

Lee, K.-S., & Jung, M.-C. (2015). Ergonomic evaluation of biomechanical hand function. *Safety and health at work, 6*, 9-17. https://doi.org/10.1016/j.shaw.2014.09.002

Lequerica, A. H., Donnell, C. S., & Tate, D. G. (2009). Patient engagement in rehabilitation therapy: Physical and occupational therapist impressions. *Disability and Rehabilitation, 31*, 753-760. https://doi.org/10.1080/09638280802309095

Levin, M. F., & Demers, M. (2021). Motor learning in neurological rehabilitation. *Disability and Rehabilitation, 43*, 3445-3453. https://doi.org/10.1080/09638288.2020.1752317

Levin, S. M., Nelson, C. O., Botts, J. D., Teplitz, G. A., Kwon, Y., & Serra-Hsu, F. (2008). Biomechanical evaluation of volar locking plates for distal radius fractures. *Hand, 3*, 55-60. https://doi.org/10.1007/s11552-007-9063-1

Lewis-Beck, M. S., Bryman, A., & Futing Liao, T. (2004). *The sage encyclopedia of social science research methods*. https://doi.org/10.4135/9781412950589

Li, Z.-M., Kuxhaus, L., Fisk, J. A., & Christophel, T. H. (2005). Coupling between wrist flexion–extension and radial–ulnar deviation. *Clinical Biomechanics, 20*, 177-183. https://doi.org/10.1016/j.clinbiomech.2004.10.002

Lichtman, D. M., Bindra, R. R., Boyer, M. I., Putnam, M. D., Ring, D., Slutsky, D. J., Taras, J. S., Watters III, W. C., Goldberg, M. J., & Keith, M. (2011). American academy of orthopaedic surgeons clinical practice guideline on: The treatment of distal radius fractures. *Journal of Bone and Joint Surgery, 93*, 775-778. https://doi.org/10.2106/jbjs.938ebo

Lin, K., Wu, C. Y., Tickle-Degnen, L., & Coster, W. (1997). Enhancing occupational performance through occupationally embedded exercise: A meta-analytic review. *The Occupational Therapy Journal of Research, 17*, 25-47. https://doi.org/10.1177/153944929701700102

Lin, K., Wu, C. Y., & Trombly, C. A. (1998). Effects of task goal on movement kinematics and line bisection performance in adults without disabilities. *American Journal of Occupational Therapy, 52*, 179-187. https://doi.org/10.5014/ajot.52.3.179

Lissek, S., Wilimzig, C., Stude, P., Pleger, B., Kalisch, T., Maier, C., Peters, S. A., Nicolas, V., Tegenthoff, M., & Dinse, H. R. (2009). Immobilization impairs tactile perception and shrinks somatosensory cortical maps. *Current Biology, 19*, 837-842. https://doi.org/10.1016/j.cub.2009.03.065

Liu, C.-j., Shiroy, D. M., Jones, L. Y., & Clark, D. O. (2014). Systematic review of functional training on muscle strength, physical functioning, and activities of daily living in older adults. *European Review of Aging and Physical Activity, 11*, 95-106. https://doi.org/10.1007/s11556-014-0144-1

Loisel, F., Bouilloux, X., Uhring, J., Rochet, S., & Obert, L. (2015). Early postoperative improvements in the quick dash score after distal radius fracture are related to the type of surgical treatment. *European Journal of Orthopaedic Surgery & Traumatology, 25*, 865-869. https://doi.org/10.1007/s00590-015-1626-1

Loisel, F., Kielwasser, H., Faivre, G., Rondot, T., Rochet, S., Adam, A., Sergent, P., Leclerc, G., Obert, L., & Lepage, D. (2018). Treatment of distal radius fractures with locking plates: An update. *European Journal of Orthopaedic Surgery and Traumatology, 28*, 1537-1542. https://doi.org/10.1007/s00590-018-2274-z

Lozano-Calderón, S. A., Souer, S., Mudgal, C., Jupiter, J. B., & Ring, D. (2008). Wrist mobilization following volar plate fixation of fractures of the distal part of the radius. *Journal of Bone and Joint Surgery, 90*, 1297-1304. https://doi.org/10.2106/jbjs.g.01368

Lucado, A. M., Li, Z., Russell, G. B., Papadonikolakis, A., & Ruch, D. S. (2008). Changes in impairment and function after static progressive splinting for stiffness after distal radius fracture. *Journal of Hand Therapy, 21*, 319-325. https://doi.org/10.1197/j.jht.2008.01.002

Lyngcoln, A., Taylor, N., Pizzari, T., & Baskus, K. (2005). The relationship between adherence to hand therapy and short-term outcome after distal radius fracture. *Journal of Hand Therapy, 18*, 2-8. https://doi.org/10.1197/j.jht.2004.10.008

Ma, H., Trombly, C. A., & Robinson-Podolski, C. (1999). The effect of context on skill acquisition and transfer. *American Journal of Occupational Therapy, 53*, 138-144. https://doi.org/10.5014/ajot.53.2.138

MacDermid, J. C. (1996, Apr-Jun). Development of a scale for patient rating of wrist pain and disability. *Journal of Hand Therapy, 9*, 178-183. https://doi.org/10.1016/S0894-1130(96)80076-7

MacDermid, J. C., Donner, A., Richards, R. S., & Roth, J. H. (2002). Patient versus injury factors as predictors of pain and disability six months after a distal radius fracture. *Journal of Clinical Epidemiology, 55*, 849-854. https://doi.org/10.1016/s0895-4356(02)00445-6

MacDermid, J. C., Richards, R. S., Donner, A., Bellamy, N., & Roth, J. H. (2000). Responsiveness of the short form-36, disability of the arm, shoulder, and hand questionnaire, patient-rated wrist evaluation, and physical impairment measurements in evaluating recovery after a distal radius fracture. *Journal of Hand Surgery, 25*, 330-340. https://doi.org/10.1053/jhsu.2000.jhsu25a0330

MacDermid, J. C., Roth, J. H., & McMurtry, R. (2007). Predictors of time lost from work following a distal radius fracture. *Journal of Occupational Rehabilitation, 17*, 47-62. https://doi.org/10.1007/s10926-007-9069-0

MacDermid, J. C., Turgeon, T., Richards, R. S., Beadle, M., & Roth, J. H. (1998). Patient rating of wrist pain and disability: A reliable and valid measurement tool. *Journal of Orthopaedic Trauma, 12*, 577-586. https://doi.org/10.1097/00005131-199811000-00009

MacFarlane, R. J., Miller, D., Wilson, L., Meyer, C., Kerin, C., Ford, D. J., & Cheung, G. (2015). Functional outcome and complications at 2.5 years following volar locking plate fixation of distal radius fractures. *Journal of Hand and Microsurgery, 7*, 18-24. https://doi.org/10.1007/s12593-014-0155-1

MacIntyre, N. J., & Dewan, N. (2016). Epidemiology of distal radius fractures and factors predicting risk and prognosis. *Journal of Hand Therapy, 29*, 136-145. https://doi.org/10.1016/j.jht.2016.03.003

Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: Guided by information power. *Qualitative Health Research, 26*, 1753-1760. https://doi.org/10.1177/1049732315617444

Mancinelli, C. A., & Davis, S. D. (2006). Range of motion and stretching. In F. E. Huber (Ed.), *Therapeutic exercise: Treatment planning for progression*. Elsevier. https://doi.org/10.2522/ptj.2007.87.5.616

Mansuripur, P. K., Gil, J. A., Cassidy, D., Kane, P., Kluk, A., Crisco, J. J., & Akelman, E. (2018). Fixation strength in full and limited fixation of osteoporotic distal radius fractures. *Hand, 13*, 461-465. https://doi.org/10.1177/1558944717708032

Manzano, A. (2016). The craft of interviewing in realist evaluation. *Evaluation, 22*, 342-360. https://doi.org/10.1177/1356389016638615

Mathiowetz, V., Kashman, N., Volland, G., Weber, K., Dowe, M., & Rogers, S. (1985). Grip and pinch strength: Normative data for adults. *Archives of Physical Medicine and Rehabilitation, 66*, 69-74.

Maxwell, J. A., & Mittapalli, K. (2010). Realism as a stance for mixed methods research. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 145-168). Sage. https://doi.org/10.4135/9781506335193.n6

McEvoy, P., & Richards, D. (2006). A critical realist rationale for using a combination of quantitative and qualitative methods. *Journal of Research in Nursing, 11*, 66-78. https://doi.org/10.1177/1744987106060192

McHugh, B. P., Morton, A. M., Akhbari, B., Molino, J., & Crisco, J. J. (2020). Accuracy of an electrogoniometer relative to optical motion tracking for quantifying wrist range of motion. *Journal of Medical Engineering & Technology, 44*, 49-54. https://doi.org/10.1080/03091902.2020.1713240

McKinnon, C. D., Ehmke, S., Kociolek, A. M., Callaghan, J. P., & Keir, P. J. (2020). Wrist posture estimation differences and reliability between video analysis and electrogoniometer methods. *Human Factors, 63*, 1284-1294. https://doi.org/10.1177/0018720820923839

McLaren, R., Joseph, F., Baguley, C., & Taylor, D. (2016). A review of e-textiles in neurological rehabilitation: How close are we? *Journal of Neuroengineering and Rehabilitation, 13*, 59-72. https://doi.org/10.1186/s12984-016-0167-0

Mehta, S., MacDermid, J. C., & Tremblay, M. (2011). The implications of chronic pain models for rehabilitation of distal radius fracture. *Hand Therapy, 16*, 2-11. https://doi.org/10.1258/ht.2010.010022

Melchert-McKearnan, K., Deitz, J., Engel, J. M., & White, O. (2000). Children with burn injuries: Purposeful activity versus rote exercise. *American Journal of Occupational Therapy, 54*, 381-390. https://doi.org/10.5014/ajot.54.4.381

Michlovitz, S. L., Harris, B. A., & Watkins, M. P. (2004). Therapy interventions for improving joint range of motion: A systematic review. *Journal of Hand Therapy, 17*, 118-131. https://doi.org/10.1197/j.jht.2004.02.002

Midgley, R., & Pisano, K. (2021). Therapist's management of the stiff hand. In T. M. Skirven, A. L. Osterman, J. Fedorczyk, P. C. Amadio, & E. K. S. Feldscher (Eds.), *Rehabilitation of the hand and upper extremity* (pp. 372-393). Elsevier Mosby.

Miller, L., & Nelson, D. L. (1987). Dual-purpose activity versus single-purpose activity in terms of duration on task, exertion level, and affect. *Occupational Therapy in Mental Health, 7*, 55-67. https://doi.org/10.1300/j004v07n01_04

Mills, J. (2014). Methodology and methods. In J. Mills & M. Birks (Eds.), *Qualitative methodology: A practical guide*. Sage. https://doi.org/10.4135/9781473920163.n3

Ministry of Health. (2014). *The guide to he korowai oranga – Māori health strategy*. Ministry of Health. https://www.health.govt.nz/our-work/populations/maori-health/he-korowai-oranga

Ministry of Research Science and Technology. (2005). *Vision mātauranga. Unlocking the innovation potential of Māori knowledge, resources and people*. https://www.mbie.govt.nz/science-and-technology/science-and-innovation/agencies-policies-and-budget-initiatives/vision-matauranga-policy/

Mitsukane, M., Sekiya, N., Himei, S., & Oyama, K. (2015). Immediate effects of repetitive wrist extension on grip strength in patients with distal radial fracture. *Archives of Physical Medicine and Rehabilitation, 96*, 862-868. https://doi.org/10.1016/j.apmr.2014.09.024

Moher, D., Hopewell, S., Schulz, K. F., Montori, V., Gotzsche, P. C., Devereaux, P. J., Elbourne, D., Egger, M., & Altman, D. G. (2010). Consort 2010 explanation and elaboration: Updated guidelines for reporting parallel group randomised trials. *BMJ, 340*, 869. https://doi.org/10.1136/bmj.c869

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic reviews, 4*, 1. https://doi.org/10.1186/2046-4053-4-1

Molineux, M. (2010). The nature of occupation. In M. Curtin, M. Molineux, & J. Webb (Eds.), *Occupational therapy and physical dysfunction: Enabling occupation* (pp. 17-26). Elsevier.

Morris, Z. S., Wooding, S., & Grant, J. (2011). The answer is 17 years, what is the question: Understanding time lags in translational research. *Journal of the Royal Society of Medicine, 104*, 510-520. https://doi.org/10.1258/jrsm.2011.110180

Morton, G. G., Barnett, D. W., & Hale, L. S. (1992). A comparison of performance measures of an added-purpose task versus a single-purpose task for upper extremities. *American Journal of Occupational Therapy, 46*, 128-133. https://doi.org/10.5014/ajot.46.2.128

Moss, D. P., Means Jr, K. R., Parks, B. G., & Forthman, C. L. (2011). A biomechanical comparison of volar locked plating of intra-articular distal radius fractures: Use of 4 versus 7 screws for distal fixation. *The Journal of Hand Surgery, 36*, 1907-1911. https://doi.org/10.1016/j.jhsa.2011.08.039

Müller, R., Gertz, K. J., Molton, I. R., Terrill, A. L., Bombardier, C. H., Ehde, D. M., & Jensen, M. P. (2016). Effects of a tailored positive psychology intervention on well-being and pain in individuals with chronic pain and a physical disability. *The Clinical Journal of Pain, 32*, 32-44. https://doi.org/10.1097/AJP.0000000000000225

Muratori, L. M., Lamberg, E. M., Quinn, L., & Duff, S. V. (2013). Applying principles of motor learning and control to upper extremity rehabilitation. *Journal of Hand Therapy, 26*, 94-103. https://doi.org/10.1016/j.jht.2012.12.007

Murgia, A., Kyberd, P. J., Chappell, P. H., & Light, C. M. (2004). Marker placement to describe the wrist movements during activities of daily living in cyclical tasks.

Clinical Biomechanics, 19, 248-254. https://doi.org/10.1016/j.clinbiomech.2003.11.012

Murphy, S. L., & Gutman, S. A. (2012). Intervention fidelity: A necessary aspect of intervention effectiveness studies. *American Journal of Occupational Therapy, 66*, 387-388. https://doi.org/10.5014/ajot.2010.005405

Myhr, H., & Collis, J. M. (2018). *Equal outcomes for maori in hand therapy* [Poster presentation]. Counties Manukau Health.

Nairn, S. (2012). A critical realist approach to knowledge: Implications for evidence-based practice in and beyond nursing. *Nursing Inquiry, 19*, 6-17. https://doi.org/10.1111/j.1440-1800.2011.00566.x

Naughton, N., & Algar, L. (2021). Therapy management of distal radius fractures. In T. M. Skirven, A. L. Osterman, J. Fedorczyk, P. C. Amadio, & E. K. S. Feldscher (Eds.), *Rehabilitation of the hand and upper extremity* (pp. 833-850). Elsevier Mosby.

Nazari, G., Bobos, P., MacDermid, J. C., Lalone, E. A., & Grewal, R. (2018). Physical impairments predict hand dexterity function after distal radius fractures: A 2-year prospective cohort study. *Hand Therapy, 23*, 64-69. https://doi.org/10.1177/1758998317751238

Nellans, K. W., Kowalski, E., & Chung, K. C. (2012). The epidemiology of distal radius fractures. *Hand Clinics, 28*, 113-125. https://doi.org/10.1016/j.hcl.2012.02.001

Nelson, D., & Peterson, C. (1989). Enhancing therapeutic exercise through purposeful activity: A theoretic analysis. *Topics in Geriatric Rehabilitation, 4*, 12-22. https://doi.org/10.1097/00013614-198907000-00004

Nelson, D. L., Cipriani, D. J., & Thomas, J. J. (2002). Physical therapy and occupational therapy: Partners in rehabilitation for persons with movement impairments. *Occupational Therapy in Health Care, 15*, 35-57. https://doi.org/10.1080/J003v15n03_03

Ng, J. L., Kersh, M. E., Kilbreath, S., & Knothe Tate, M. (2017). Establishing the basis for mechanobiology-based physical therapy protocols to potentiate cellular healing and tissue regeneration. *Frontiers in Physiology, 8*, 1-13. https://doi.org/10.3389/fphys.2017.00303

Nguyen, N., Pham, T., Pathirana, P. N., Babazadeh, S., & Page, R. (2015). *Real-time measurement of radiocarpal joint angle during dart-thrower's movement* Biomedical Engineering International Conference (BMEiCON-2015), http://hdl.handle.net/10536/DRO/DU:30081636

Nielsen, K. T., la Cour, K., Christensen, J. R., Pilegaard, M. S., von Bülow, C., Brandt, Å., Peoples, H., Jonsson, H., & Wæhrens, E. E. (2020). Lessons learned about occupation-focused and occupation-based interventions: A synthesis using group concept mapping methodology. *Scandinavian Journal of Occupational Therapy, 27*, 481-492. https://doi.org/10.1080/11038128.2018.1561940

Nizamis, K., Rijken, N. H. M., Mendes, A., Janssen, M., Bergsma, A., & Koopman, B. (2018). A novel setup and protocol to measure the range of motion of the wrist and the hand. *Sensors (Basel), 18*, 3230. https://doi.org/10.3390/s18103230

O'Brien, B. C., Harris, I. B., Beckman, T. J., Reed, D. A., & Cook, D. A. (2014). Standards for reporting qualitative research: A synthesis of recommendations. *Academic Medicine, 89*, 1245-1251. https://doi.org/10.1097/acm.0000000000000388

Ojima, H., Miyake, S., Kumashiro, M., Togami, H., & Suzuki, K. (1991). Dynamic analysis of wrist circumduction: A new application of the biaxial flexible electrogoniometer. *Clinical Biomechanics, 6*, 221-229. https://doi.org/10.1016/0268-0033(91)90050-z

Olufemi-Yusuf, D., Gabriel, S., Makhinova, T., & Guirguis, L. (2018). "Being in control of my asthma myself" patient experience of asthma management: A qualitative interpretive description. *Pharmacy, 6*, 121. https://doi.org/10.3390/pharmacy6040121

Omar, M. T. A., Hegazy, F. A., & Mokashi, S. P. (2012). Influences of purposeful activity versus rote exercise on improving pain and hand function in pediatric burn. *Burns, 38*, 261-268. https://doi.org/10.1016/j.burns.2011.08.004

Orbay, J. L., & Touhami, A. (2006). Current concepts in volar fixed-angle fixation of unstable distal radius fractures. *Clinical orthopaedics and related research, 445*, 58-67. https://doi.org/10.1097/01.blo.0000205891.96575.0f

Orellano, E., Colón, W. I., & Arbesman, M. (2012). Effect of occupation-and activity-based interventions on instrumental activities of daily living performance among community-dwelling older adults: A systematic review. *American Journal of Occupational Therapy, 66*, 292-300. https://doi.org/10.5014/ajot.2012.003053

Osada, D., Kamei, S., Masuzaki, K., Takai, M., Kameda, M., & Tamai, K. (2008). Prospective study of distal radius fractures treated with a volar locking plate system. *Journal of Hand Surgery, 33*, 691-700. https://doi.org/10.1016/j.jhsa.2008.01.024

Osada, D., Viegas, S. F., Shah, M. A., Morris, R. P., & Patterson, R. M. (2003). Comparison of different distal radius dorsal and volar fracture fixation plates: A biomechanical study. *Journal of Hand Surgery 28*, 94-104. https://doi.org/10.1053/jhsu.2003.50016

Palmer, A. K., Werner, F. W., Murphy, D., & Glisson, R. (1985). Functional wrist motion: A biomechanical study. *The Journal of Hand Surgery, 10*, 39-46. https://doi.org/10.1016/s0363-5023(85)80246-x

Perez-Marmol, J. M., Garcia-Rios, M. C., Ortega-Valdivieso, M. A., Cano-Deltell, E. E., Peralta-Ramirez, M. I., Ickmans, K., & Aguilar-Ferrandiz, M. E. (2017). Effectiveness of a fine motor skills rehabilitation program on upper limb disability, manual dexterity, pinch strength, range of fingers motion, performance in activities of daily living, functional independency, and general self-efficacy in hand osteoarthritis: A randomized clinical trial. *Journal of Hand Therapy, 30*, 262-273. https://doi.org/10.1016/j.jht.2016.12.001

Pérez-Mármol, J. M., Ortega-Valdivieso, M. A., Cano-Deltell, E. E., Peralta-Ramírez, M. I., García-Ríos, M. C., & Aguilar-Ferrándiz, M. E. (2016). Influence of upper limb disability, manual dexterity and fine motor skill on general self-efficacy in institutionalized elderly with osteoarthritis. *Journal of Hand Therapy, 29*, 58-65. https://doi.org/10.1016/j.jht.2015.12.001

Perlman, C., & Bergthorson, M. (2017). Task, activity and occupational analysis. In M. Curtin, M. Egan, & J. Adams (Eds.), *Occupational therapy for people experiencing illness, injury or impairment* (pp. 192-206). Elsevier.

Persson, D., & Erlandsson, L. (2010). Evaluating OVal-9, an instrument for detecting experiences of value in daily occupations. *Occupational Therapy in Mental Health, 26*, 32-50. https://doi.org/10.1080/01642120903515284

Persson, D., Erlandsson, L., Eklund, M., & Iwarsson, S. (2001). Value dimensions, meaning, and complexity in human occupation - a tentative structure for analysis. *Scandinavian Journal of Occupational Therapy, 8*, 7-18. https://doi.org/10.1080/11038120119727

Pham, T., Pathirana, P. N., Trinh, H., & Fay, P. (2015). A non-contact measurement system for the range of motion of the hand. *Sensors, 15*, 18315-18333. https://doi.org/10.3390/s150818315

Pierce, D. (2001). Occupation by design: Dimensions, therapeutic power, and creative process. *American Journal of Occupational Therapy, 55*, 249-259. https://doi.org/10.5014/ajot.55.3.249

Ploegmakers, J., The, B., Wang, A., Brutty, M., & Ackland, T. (2015). Supination and pronation strength deficits persist at 2-4 years after treatment of distal radius fractures. *Hand Surgery, 20*, 430-434. https://doi.org/10.1142/S0218810415500355

Pluye, P., & Hong, Q. N. (2014). Combining the power of stories and the power of numbers: Mixed methods research and mixed studies reviews. *Annual Review of Public Health, 35*, 29-45. https://doi.org/10.1146/annurev-publhealth-032013-182440

Podoly, T. Y., & Sasson, A. B. (2020). When it's impossible to ignore: Development and validation of the sensory habituation questionnaire. *American Journal of Occupational Therapy, 74*, 7403205040p7403205041-7403205040p7403205010. https://doi.org/10.5014/ajot.2020.033878

Polatajko, H. J., & Davis, J. A. (2012). Advancing occupation-based practice: Interpreting the rhetoric. *Canadian journal of occupational therapy, 79*, 259-262. https://doi.org/10.2182/CJOT.2012.79.5.1

Polatajko, H. J., Davis, J. A., Hobson, S. J., Landry, J. E., Mandich, A., Street, S. L., Whippey, E., & Yee, S. (2004). Meeting the responsibility that comes with the privilege: Introducing a taxonomic code for understanding occupation. *Canadian journal of occupational therapy, 71*, 261-264. https://doi.org/10.1177/000841740507200307

Poulsen, H. S., & Hansen, A. Ø. (2018). Occupational performance problems identified by 507 patients: An insight that can guide occupation-based hand therapy. *Hand Therapy, 23*, 121-129. https://doi.org/10.1177/1758998318784316

Price, P., & Miner, S. (2007). Occupation emerges in the process of therapy. *American Journal of Occupational Therapy, 61*, 441-450. https://doi.org/10.5014/ajot.61.4.441

Putnam, M. D., Meyer, N. J., Nelson, E. W., Gesensway, D., & Lewis, J. L. (2000). Distal radial metaphyseal forces in an extrinsic grip model: Implications for postfracture rehabilitation. *The Journal of Hand Surgery, 25*, 469-475. https://doi.org/10.1053/jhsu.2000.6915

Quadlbauer, S., Pezzei, C., Jurkowitsch, J., Kolmayr, B., Keuchel, T., Simon, D., Hausner, T., & Leixnering, M. (2017). Early rehabilitation of distal radius fractures stabilized by volar locking plate: A prospective randomized pilot study. *Journal of Wrist Surgery, 6*, 102-112. https://doi.org/10.1055/s-0036-1587317

Quadlbauer, S., Pezzei, C., Jurkowitsch, J., Rosenauer, R., Kolmayr, B., Keuchel, T., Simon, D., Beer, T., Hausner, T., & Leixnering, M. (2020). Rehabilitation after distal radius fractures: Is there a need for immobilization and physiotherapy? *Archives of Orthopaedic and Trauma Surgery, 140*, 651-663. https://doi.org/10.1007/s00402-020-03367-w

Rashid, A., & Hasan, O. (2018). Wearable technologies for hand joints monitoring for rehabilitation: A survey. *Microelectronics Journal*. https://doi.org/10.1016/j.mejo.2018.01.014

Rawes, M., Richardson, J., & Dias, J. (1996). A new technique for the assessment of wrist movement using a biaxial flexible electrogoniometer. *Journal of Hand Surgery, 21*, 600-603. https://doi.org/10.1016/S0266-7681(96)80138-0

Reed, K., Hocking, C., & Smythe, L. (2013). The meaning of occupation: Historical and contemporary connections between health and occupation. *New Zealand Journal of Occupational Therapy, 60*, 38. https://doi.org/10.3316/informit.267348427627529

Rice, M. S., Alaimo, A. J., & Cook, J. A. (1999). Movement dynamics and occupational embeddedness in a grasping and placing task. *Occupational Therapy International, 6*, 298-310. https://doi.org/10.1002/oti.103

Rice, M. S., Davies, D. M., & Maitra, K. (2009). Immediate versus prolonged visual exposure and object relevancy in a reaching and placing task. *Al Ameen Journal of Medical Sciences, 2*, 22-35.

Rice, M. S., & Renock, L. A. (2006). Personal preference and quality of reach in healthy adult women. *American Journal of Occupational Therapy, 60*, 577-586. https://doi.org/10.5014/ajot.60.5.577

Rikli, D. A., Honigmann, P., Babst, R., Cristalli, A., Morlock, M. M., & Mittlmeier, T. (2007). Intra-articular pressure measurement in the radioulnocarpal joint using a novel sensor: In vitro and in vivo results. *The Journal of Hand Surgery, 32*, 67-75. https://doi.org/10.1016/j.jhsa.2006.10.007

Robert-Lachaine, X., Mecheri, H., Larue, C., & Plamondon, A. (2017). Validation of inertial measurement units with an optoelectronic system for whole-body motion analysis. *Medical & Biological Engineering & Computing, 55*, 609-619. https://doi.org/10.1007/s11517-016-1537-2

Robinson, L. S., Brown, T., & O'Brien, L. (2016, Aug). Embracing an occupational perspective: Occupation-based interventions in hand therapy practice. *Australian Occupational Therapy Journal, 63*, 293-296. https://doi.org/10.1111/1440-1630.12268

Robson, B., Purdie, G., Simmonds, S., Waa, A., Scorringe, K., & Rameka, R. (2015). *Counties Manukau District Health Board Māori health profile 2015*. Te Rōpū Rangahau Hauora a Eru Pōmare. https://countiesmanukau.health.nz/assets/About-CMH/Performance-and-planning/health-status/2015-counties-manukau-DHB-maori-health-profile.pdf

Roh, Y. H., Lee, B. K., Noh, J. H., Baek, J. R., Oh, J. H., Gong, H. S., & Baek, G. H. (2014, Dec). Factors associated with complex regional pain syndrome type 1 in patients with surgically treated distal radius fracture. *Archives of Orthopaedic and Trauma Surgery, 134*, 1775-1781. https://doi.org/10.1007/s00402-014-2094-5

Ross, L. M., & Nelson, D. L. (2000). Comparing materials-based occupation, imagery-based occupation, and rote movement through kinematic analysis of reach. *The Occupational Therapy Journal of Research, 20*, 45-60. https://doi.org/10.1177/153944920002000103

Ryu, J., Cooney, W. P., Askew, L. J., An, K.-N., & Chao, E. Y. (1991). Functional ranges of motion of the wrist joint. *The Journal of Hand Surgery, 16*, 409-419. https://doi.org/10.1016/0363-5023(91)90006-w

Sackaloo, K., Strouse, E., & Rice, M. S. (2015). Degree of preference and its influence on motor control when reaching for most preferred,neutrally preferred, and least preferred candy. *OTJR Occupation, Participation and Health, 35*, 81-88. https://doi.org/10.1177/1539449214561763

Saggio, G. (2014). A novel array of flex sensors for a goniometric glove. *Sensors and Actuators A: Physical, 205*, 119-125. https://doi.org/10.1016/j.sna.2013.10.030

Salibian, A. A., Bruckman, K. C., Bekisz, J. M., Mirrer, J., Thanik, V. D., & Hacquebord, J. H. (2019). Management of unstable distal radius fractures: A survey of hand surgeons. *Journal of Wrist Surgery*. https://doi.org/10.1055/s-0038-1675792

Sandelowski, M. (2000). Combining qualitative and quantitative sampling, data collection, and analysis techniques in mixed-method studies. *Research in Nursing and Health, 23*, 246-255. https://doi.org/10.1002/1098-240x(200006)23:3<246::aid-nur9>3.0.co;2-h

Schmidt, R. A., & Wrisberg, C. A. (Eds.). (2008). *Motor learning and performance: A situation-based learning approach* (3rd ed.). Human Kinetics Press.

Schneppendahl, J., Windolf, J., & Kaufmann, R. A. (2012). Distal radius fractures: Current concepts. *Journal of Hand Surgery, 37*, 1718-1725. https://doi.org/10.1016/j.jhsa.2012.06.001

Scotland, J. (2012). Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. *English Language Teaching, 5*, 9-16. https://doi.org/10.5539/elt.v5n9p9

Seo, N. J., Sindhu, B. S., & Shechtman, O. (2011). Influence of pain associated with musculoskeletal disorders on grip force timing. *Journal of Hand Therapy, 24*, 335-344. https://doi.org/10.1016/j.jht.2011.06.004

Shefer Eini, D., Ratzon, N. Z., Rizzo, A. A., Yeh, S. C., Lange, B., Yaffe, B., Daich, A., Weiss, P. L., & Kizony, R. (2017). Camera-tracking gaming control device for evaluation of active wrist flexion and extension. *Journal of Hand Therapy, 30*, 89-96. https://doi.org/10.1016/j.jht.2016.07.002

Shimose, R., Matsunaga, A., & Muro, M. (2011). Effect of submaximal isometric wrist extension training on grip strength. *European Journal of Applied Physiology, 111*, 557-565. https://doi.org/10.1007/s00421-010-1675-4

Shiratsu, A., & Coury, H. (2003). Reliability and accuracy of different sensors of a flexible electrogoniometer. *Clinical Biomechanics, 18*, 682-684. https://doi.org/10.1016/S0268-0033(03)00110-4

Siengsukon, C. F. (2012). Neuroplasticity. In L. Lundy-Ekman (Ed.), *Neuroscience: Fundamentals for rehabilitation* (pp. 66-80). Elsevier. http://ebookcentral.proquest.com/lib/aut/detail.action?docID=2072328

Singh, H. P., Bhattacharjee, D., Dias, J., & Trail, I. (2017). Dynamic assessment of the wrist after total wrist arthroplasty. *Journal of Hand Surgery (European Volume), 42*, 573-579. https://doi.org/10.1177/1753193417690472

Singh, H. P., Brinkhorst, M. E., Dias, J. J., Moojen, T., Hovius, S., & Bhowal, B. (2014). Dynamic assessment of wrist after proximal row carpectomy and 4-corner fusion. *The Journal of Hand Surgery, 39*, 2424-2433. https://doi.org/10.1016/j.jhsa.2014.09.005

Singh, H. P., Dias, J. J., Slijper, H., & Hovius, S. (2012). Assessment of velocity, range, and smoothness of wrist circumduction using flexible electrogoniometry. *Journal of Hand Surgery, 37*, 2331-2339. https://doi.org/10.1016/j.jhsa.2012.08.025

Small, C., Bryant, J., Dwosh, I., Griffiths, P., Pichora, D., & Zee, B. (1996). Validation of a 3d optoelectronic motion analysis system for the wrist joint. *Clinical Biomechanics, 11*, 481-483. https://doi.org/ 10.1016/S0268-0033(96)00042-3

Smeragliuolo, A. H., Hill, J., Disla, L., & Putrino, D. (2016). Validation of the leap motion controller using markered motion capture technology. *Journal of Biomechanics, 49*, 1742-1750. https://doi.org/10.1016/j.jbiomech.2016.04.006

Smith-Forbes, E. V., Howell, D. M., Willoughby, J., Armstrong, H., Pitts, D. G., & Uhl, T. L. (2016). Adherence of individuals in upper extremity rehabilitation: A qualitative study. *Archives of Physical Medicine and Rehabilitation, 97*, 1262-1268. e1261. https://doi.org/10.1016/j.apmr.2015.11.008

Smith, C., & Elger, T. (2014). Critical realism and interviewing subjects. In P. K. Edwards, J. O'Mahoney, & S. Vincent (Eds.), *Studying organizations using critical realism: A practical guide* (pp. 109-131). Oxford University Press.

Smith, D. W., Brou, K. E., & Henry, M. H. (2004). Early active rehabilitation for operatively stabilized distal radius fractures. *Journal of Hand Therapy, 17*, 43-49. https://doi.org/10.1197/j.jht.2003.10.006

Smith, J. M., Werner, F. W., & Harley, B. J. (2018). Forces in the distal radius during a pushup or active wrist motions. *The Journal of Hand Surgery, 43*(9), 806-811.

Soo-Young, C., & Jin-Yong, K. (2012). Comparison of an electrogoniometer with the fisi metrix program in the assessment of wrist deviation. *Journal of Physical Therapy Science, 24*, 735-737. https://doi.org/10.1589/jpts.24.735

Squires, J. E., Valentine, J. C., & Grimshaw, J. M. (2013). Systematic reviews of complex interventions: Framing the review question. *Journal of Clinical Epidemiology, 66*, 1215-1222. https://doi.org/10.1016/j.jclinepi.2013.05.013

Steinbeck, T. M. (1986). Purposeful activity and performance. *American Journal of Occupational Therapy, 40*, 529-534. https://doi.org/10.5014/ajot.40.8.529

Stenner, R., Palmer, S., & Hammond, R. (2018). What matters most to people in musculoskeletal physiotherapy consultations? A qualitative study. *Musculoskeletal Science and Practice, 35*, 84-89. https://doi.org/10.1016/j.msksp.2018.03.005

Stephens, G., Littlewood, C., Foster, N. E., & Dikomitis, L. (2020). Rehabilitation following rotator cuff repair: A nested qualitative study exploring the perceptions and experiences of participants in a randomised controlled trial. *Clinical Rehabilitation*, 911-919. https://doi.org/10.1177/0269215520984025

Stern, B. Z., Njelesani, J., & Howe, T.-H. (2021). Transitioning from hurting to healing: Self-management after distal radius fracture. *Disability and Rehabilitation, Aug*. https://doi.org/10.1080/09638288.2021.1962990

Stirling, E. R., Johnson, N. A., & Dias, J. J. (2018). Epidemiology of distal radius fractures in a geographically defined adult population. *Journal of Hand Surgery, European Volume, 43*, 974-982. https://doi.org/10.1177/1753193418786378

StretchSense. Retrieved January 23, 2019 from https://www.stretchsense.com/

Suso-Martí, L., La Touche, R., Angulo-Díaz-Parreño, S., & Cuenca-Martínez, F. (2020). Effectiveness of motor imagery and action observation training on musculoskeletal pain intensity: A systematic review and meta-analysis. *European Journal of Pain, 24*, 886-901. https://doi.org/10.1002/ejp.1540

Swart, E., Nellans, K., & Rosenwasser, M. (2012, May). The effects of pain, supination, and grip strength on patient-rated disability after operatively treated distal radius fractures. *Journal of Hand Surgery, 37*, 957-962. https://doi.org/10.1016/j.jhsa.2012.01.028

Tariq, S., & Woodman, J. (2013). Using mixed methods in health research. *Journal of the Royal Society of Medicine Short Reports, 4*, 1-8. https://doi.org/10.1177/2042533313479197

Taylor, S. A., Kedgley, A. E., Humphries, A., & Shaheen, A. F. (2018). Simulated activities of daily living do not replicate functional upper limb movement or reduce movement variability. *Journal of Biomechanics, 76*, 119-128. https://doi.org/10.1016/j.jbiomech.2018.05.040

Teodoro, I. P. P., Rebouças, V. d. C. F., Thorne, S. E., Souza, N. K. M. d., Brito, L. S. A. d., & Alencar, A. M. P. G. (2018). Interpretive description: A viable methodological approach for nursing research. *Escola Anna Nery, 22*, 1-8. https://doi.org/10.1590/2177-9465-ean-2017-0287

Terry, G., Hayfield, N., Clarke, V., & Braun, V. (2017). Thematic analysis. In C. Willig & W. S. Rogers (Eds.), *The sage handbook of qualitative research in psychology* (pp. 17-37). SAGE Publications Ltd. https://doi.org/10.4135/9781526405555

Thorne, S. (2016a). Constructing data. In *Interpretive description* (pp. 113-130). Routledge. https://doi.org/10.4324/9781315545196

Thorne, S. (2016b). Entering the field. In *Interpretive description* (pp. 99-111). Routledge. https://doi.org/10.4324/9781315545196

Thorne, S. (2016c). *Interpretive description* (2nd ed.). Routledge. https://doi.org/10.4324/9781315545196

Thorne, S. (2016d). Scaffolding a study. In *Interpretive description* (pp. 50-66). Routledge. https://doi.org/10.4324/9781315545196

Thorne, S. (2016e). Transforming data. In *Interpretive description* (pp. 146-167). Routledge. https://doi.org/10.4324/9781315545196

Thorne, S. (2018). What can qualitative studies offer in a world where evidence drives decisions? *Asia-Pacific Journal of Oncology Nursing, 5*, 43-45. https://doi.org/10.4103/apjon.apjon_51_17

Thorne, S., Kirkham, S. R., & MacDonald-Emes, J. (1997). Interpretive description: A noncategorical qualitative alternative for developing nursing knowledge. *Research in Nursing and Health, 20*, 169-177. https://doi.org/10.1002/(SICI)1098-240X(199704)20:2<169::AID-NUR9>3.0.CO;2-I

Timans, R., Wouters, P., & Heilbron, J. (2019). Mixed methods research: What it is and what it could be. *Theory and Society, 48*, 193-216. https://doi.org/10.1007/s11186-019-09345-5

Törnquist, K., & Sonn, U. (1994). Towards an adl taxonomy for occupational therapists. *Scandinavian Journal of Occupational Therapy, 1*, 69-76. https://doi.org/10.3109/11038128.2014.952885

Tremayne, A., Taylor, N., Mcburney, H., & Baskus, K. (2002). Correlation of impairment and activity limitation after wrist fracture. *Physiotherapy Research International, 7*, 90-99. https://doi.org/10.1002/pri.245

Valdes, K. (2009). A retrospective pilot study comparing the number of therapy visits required to regain functional wrist and forearm range of motion following volar plating of a distal radius fracture. *Journal of Hand Therapy, 22*, 312-397. https://doi.org/10.1016/j.jht.2009.06.003

Valdes, K., & Marik, T. (2010). A systematic review of conservative interventions for osteoarthritis of the hand. *Journal of Hand Therapy, 23*(4), 334-350; quiz 351. https://doi.org/10.1016/j.jht.2010.05.001

Valdes, K., Naughton, N., & Algar, L. (2014). Sensorimotor interventions and assessments for the hand and wrist: A scoping review. *Journal of Hand Therapy, 27*, 272-286. https://doi.org/10.1016/j.jht.2014.07.002

Valevicius, A. M., Jun, P. Y., Hebert, J. S., & Vette, A. H. (2018). Use of optical motion capture for the analysis of normative upper body kinematics during functional upper limb tasks: A systematic review. *Journal of Electromyography and Kinesiology, 40*, 1-15. https://doi.org/10.1016/j.jelekin.2018.02.011

van Andel, C. J., Wolterbeek, N., Doorenbosch, C. A., Veeger, D. H., & Harlaar, J. (2008). Complete 3d kinematics of upper extremity functional tasks. *Gait and Posture, 27*, 120-127. https://doi.org/10.1016/j.gaitpost.2007.03.002

Van Vliet, P. M., & Heneghan, N. R. (2006). Motor control and the management of musculoskeletal dysfunction. *Manual Therapy, 11*, 208-213. https://doi.org/10.1016/j.math.2006.03.009

Vega-Gonzalez, A., Bain, B., Dall, P., & Granat, M. H. (2007). Continuous monitoring of upper-limb activity in a free-living environment: A validation study. *Medical & Biological Engineering & Computing, 45*, 947-956. https://doi.org/10.1007/s11517-007-0233-7

Vincent, S., & O'Mahoney, J. (2018). Critical realism and qualitative research:An introductory overview. In C. Cassell, A. L. Cunliffe, & G. Grandy (Eds.), *The SAGE Handbook of Qualitative Business and Management Research Methods: History and Traditions* (pp. 201-216). SAGE Publications Ltd. https://doi.org/10.4135/9781526430212

Vranceanu, A.-M., Cooper, C., & Ring, D. (2009). Integrating patient values into evidence-based practice: Effective communication for shared decision-making. *Hand Clinics, 25*, 83-96. https://doi.org/10.1016/j.hcl.2008.09.003

Wagner, M. R., Krauss, A., & Horowitz, B. (1995). Occupationally embedded exercise, rote exercise, and the presence of another person in an exercise context. *The Israeli Journal of Occupational Therapy, 4*, 397-402. https://www.jstor.org/stable/23460117

Walmsley, C. P., Williams, S. A., Grisbrook, T., Elliott, C., Imms, C., & Campbell, A. (2018). Measurement of upper limb range of motion using wearable sensors: A systematic review. *Sports medicine-open, 4*, 53. https://doi.org/10.1186/s40798-018-0167-7

Wan, X., Wang, W., Liu, J., & Tong, T. (2014). Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Medical Research Methodology, 14*, 135. https://doi.org/10.1186/1471-2288-14-135

Wang, Q., Markopoulos, P., Yu, B., Chen, W., & Timmermans, A. (2017). Interactive wearable systems for upper body rehabilitation: A systematic review. *Journal of Neuroengineering and Rehabilitation, 14*, 20. https://doi.org/10.1186/s12984-017-0229-y

Waterbury, K., Husband, J., Callinan, N., & Reams, M. (2016, 2016/07/01/). Beyond the research: An accelerated rehabilitation protocol for patients with distal radius fracture treated with open reduction internal fixation using volar locking plate, a retrospective review and comparison of outcomes with a surgeon directed independent exercise program. *Journal of Hand Therapy, 29*, 372-373. https://doi.org/10.1016/j.jht.2014.08.023

Watson, N. J., Haines, T., Tran, P., & Keating, J. L. (2018). A comparison of the effect of one, three, or six weeks of immobilization on function and pain after open reduction and internal fixation of distal radial fractures in adults: A randomized controlled trial. *Journal of Bone and Joint Surgery, 100*, 1118-1125. https://doi.org/10.2106/jbjs.17.00912

Watson, N. J., Martin, S. A., & Keating, J. L. (2018). The impact of wrist fracture, surgical repair and immobilization on patients: A qualitative study. *Clinical Rehabilitation, 32*, 841-851. https://doi.org/10.1177/0269215518754614

Weinstock-Zlotnick, G., & Mehta, S. (2018). A systematic review of the benefits of occupation-based intervention for patients with upper extremity musculoskeletal disorders. *Journal of Hand Therapy, 32*, 141-152. https://doi.org/10.1016/j.jht.2018.04.001

Westlake, K. P., & Byl, N. N. (2013). Neural plasticity and implications for hand rehabilitation after neurological insult. *Journal of Hand Therapy, 26*, 87-93. https://doi.org/10.1016/j.jht.2012.12.009

Wilcke, M. K. T., Abbaszadegan, H., & Adolphson, P. Y. (2007). Patient-perceived outcome after displaced distal radius fractures: A comparison between radiological parameters, objective physical variables, and the dash score. *Journal of Hand Therapy, 20*, 290-299. https://doi.org/10.1197/j.jht.2007.06.001

Wilcke, M. K. T., Abbaszadegan, H., & Adolphson, P. Y. (2011). Wrist function recovers more rapidly after volar locked plating than after external fixation but the outcomes are similar after 1 year. *Acta Orthopaedica, 82*(1), 76-81. https://doi.org/10.3109/17453674.2011.552781

Wilcke, M. K. T., Hammarberg, H., & Adolphson, P. Y. (2013). Epidemiology and changed surgical treatment methods for fractures of the distal radius. *Acta Orthopaedica, 84*, 292-296. https://doi.org/10.3109/17453674.2013.792035

Williams, L., Rycroft-Malone, J., & Burton, C. R. (2017). Bringing critical realism to nursing practice: Roy bhaskar's contribution. *Nursing Philosophy, 18*, 1-11. https://doi.org/10.1111/nup.12130

Willig, C. (2013a). Epistemological bases for qualitative research. In *Introducing qualitative research in psychology* (pp. 14-22). McGraw-hill education.

Willig, C. (2013b). From recipes to adventures. In *Introducing qualitative research in psychology* (3rd ed., pp. 3-13). McGraw-hill education.

Wilson, L., Roden, P., Taylor, Y., & Marston, L. (2008). The effectiveness of origami on overall hand function after injury: A pilot controlled trial. *The British Journal of Hand Therapy, 13*, 12-20. https://doi.org/10.1177/175899830801300102

Woby, S. R., Roach, N. K., Urmston, M., & Watson, P. J. (2005). Psychometric properties of the TSK-11: A shortened version of the tampa scale for kinesiophobia. *Pain, 117*, 137-144. https://doi.org/10.1016/j.pain.2005.05.029

Wollstein, R., Harel, H., Lavi, I., Allon, R., & Michael, D. (2018). Postoperative treatment of distal radius fractures using sensorimotor rehabilitation. *Journal of Wrist Surgery, 8*, 2-9. https://doi.org/10.1055/s-0038-1672151

Wright-St Clair, V. A., Rapson, A., Kepa, M., Connolly, M., Keeling, S., Rolleston, A., Teh, R., Broad, J. B., Dyall, L., & Jatrana, S. (2017). Ethnic and gender differences in preferred activities among Māori and non-Māori of advanced age in new zealand. *Journal of Cross-Cultural Gerontology, 32*, 433-446. https://doi.org/10.1007/s10823-017-9324-6

Wright-St Clair, V. A., Kepa, M., Hoenle, S., Hayman, K., Keeling, S., Connolly, M., Broad, J., Dyall, L., & Kerse, N. (2012). Doing what's important: Valued activities for older new zealand Māori and non-Māori. *Australasian Journal on Ageing, 31*, 241-246. https://doi.org/10.1111/j.1741-6612.2011.00583.x

Wu, C. Y., Trombly, C. A., & Lin, K. (1994). The relationship between occupational form and occupational performance: A kinematic perspective. *American Journal of Occupational Therapy, 48*, 679-687. https://doi.org/10.5014/ajot.48.8.679

Wu, C. Y., Trombly, C. A., Lin, K., & Tickle-Degnen, L. (1998). Effects of object affordances on reaching performance in persons with and without cerebrovascular accident. *American Journal of Occupational Therapy, 52*, 447-456. https://doi.org/10.5014/ajot.52.6.447

Wu, G., Van der Helm, F., Veeger, H., Makhsous, M., Van Roy, P., Anglin, C., Nagels, J., Karduna, A. R., McQuade, K., & Wang, X. (2005). International society of biomechanics. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—part ii: Shoulder, elbow, wrist and hand. *Journal of Biomechanics, 38*, 981-992.

Yamato, T., Maher, C., Saragiotto, B., Catley, M., & Moseley, A. (2018). Rasch analysis suggested that items from the template for intervention description and replication (TIDieR) checklist can be summed to create a score. *Journal of Clinical Epidemiology, 101*, 28-34. https://doi.org/10.1016/j.jclinepi.2018.05.014

Yang, C. C., & Hsu, Y. L. (2010). A review of accelerometry-based wearable motion detectors for physical activity monitoring. *Sensors (Basel), 10*, 7772-7788. https://doi.org/10.3390/s100807772

Yang, Z., Lim, P. P. H., Teo, S. H., Chen, H., Qiu, H., & Pua, Y. H. (2018, May 11). Association of wrist and forearm range of motion measures with self-reported functional scores amongst patients with distal radius fractures: A longitudinal study. *BMC Musculoskeletal Disorders, 19*, 142. https://doi.org/10.1186/s12891-018-2065-z

Yayama, T., Kobayashi, S., Kokubo, Y., Inukai, T., Mizukami, Y., Kubota, M., Ishikawa, J., Baba, H., & Minami, A. (2007). Motion analysis of the wrist joints in patients with rheumatoid arthritis. *Modern Rheumatology, 17*, 322-326. https://doi.org/10.3109/s10165-007-0590-y

Ydreborg, K., Engstrand, C., Steinvall, I., & Larsson, E. L. (2015, Jan-Feb). Hand function, experienced pain, and disability after distal radius fracture. *American Journal of Occupational Therapy, 69*, 1-7. https://doi.org/10.5014/ajot.2015.013102

Yuan, Z. Z., Yang, Z., Liu, Q., & Liu, Y. M. (2018). Complications following open reduction and internal fixation versus external fixation in treating unstable distal radius fractures: Grading the evidence through a meta-analysis. *Orthopaedics & Traumatology, Surgery & Research, 104*, 95-103. https://doi.org/10.1016/j.otsr.2017.08.020

Yucel, R. (2018). Scientists' ontological and epistemological views about science from the perspective of critical realism. *Science & Education, 27*, 407-433. https://doi.org/10.1007/s11191-018-9983-x

Zeckey, C., Späth, A., Kieslich, S., Kammerlander, C., Böcker, W., Weigert, M., & Neuerburg, C. (2020). Early mobilization versus splinting after surgical management of distal radius fractures. *Deutsches Arzteblatt international, 117*, 445-451. https://doi.org/10.3238/arztebl.2020.0445

Ziebart, C., Nazari, G., & MacDermid, J. C. (2019). Therapeutic exercise for adults post-distal radius fracture: An overview of systematic reviews of randomized controlled trials. *Hand Therapy, 24*, 69-81. https://doi.org/10.1177/1758998319865751

Zovko, J. (2018). Some problems with scientific relativism and moral realism. *Axiomathes, 28*, 665-678. https://doi.org/10.1007/s10516-018-9400-8

Appendices

Appendix A. Study I published article: A systematic review of the influence of purposeful activities on upper extremity motor performance

Article

Influence of Purposeful Activities on Upper Extremity Motor Performance: A Systematic Review

OTJR: Occupation, Participation and Health
2020, Vol. 40(4) 223–234

DOI: 10.1177/1539449220912187
journals.sagepub.com/home/otj
SAGE

Julie M. Collis[1], Nada Signal[1], Elizabeth Mayland[2], and Valerie A. Wright-St Clair[1]

Abstract

Following upper extremity injury, exercise-approaches are commonly used to address motor impairments. Occupation-based approaches are also used but less widely promoted and their mechanisms of action not well-understood. Movement performed during purposeful activities and occupations may yield better motor performance than during nonpurposeful tasks. This review investigated the influence of engagement in purposeful activities and occupations on upper extremity motor performance in healthy and musculoskeletal populations. Databases were searched for studies in healthy or upper extremity musculoskeletal–injured adults that compared motor performance during purposeful activities against nonpurposeful movements. Twenty-one studies of moderate quality, conducted predominantly in healthy populations, were included. Upper extremity movement quantity and quality were enhanced when performed during purposeful conditions. Purposeful activities have potential to be used following injury to enhance movement and address motor impairments to a greater extent than is currently promoted. Research in musculoskeletal populations is required.

Keywords

occupation, rehabilitation, systematic review

Trauma or pathology to the wrist or hand can result in impairment and issues with performance of daily occupations that can persist for weeks or months following injury. Sensorimotor impairments include pain, joint stiffness, weakness, poor dexterity, impaired sensory discrimination, and disrupted body perception (Karagiannopoulos et al., 2013). Patient satisfaction is low and functional outcomes are poorer among patients with such impairments (Chung & Haas, 2009). Qualitative and observational data confirm the long-term functional impacts, with individuals often obligated to adopt compensatory strategies such as allowing longer time, using the contralateral hand or changing the type of grip, to carry out daily activities (Bialocerkowski, 2002).

Occupational, physical or hand therapists use a range of approaches to restore motion and function to the upper extremity following injury. Therapy often has a strong focus on range of movement exercises, particularly in the early weeks of healing (Bruder et al., 2017). Although exercises are fundamental to wrist and hand injury rehabilitation, they may be no more effective in reducing physical impairments than advice or no intervention (Bruder et al., 2017). Movement can also be intentionally promoted during daily activities and occupations but is less widely described in the literature as a therapeutic approach, than exercise approaches (Colaianni & Provident, 2010; Dy & Yancosek, 2017), Clinical observations suggest that therapists frequently use purposeful activities and occupations to facilitate joint movement, yet the rationale for using activities in this manner remains relatively unexplored. The review addresses the question of whether engaging in purposeful activities and occupations has a beneficial influence on movement of the upper extremity after injury compared with nonpurposeful movements or tasks.

Although the terms activity and occupation are sometimes used interchangeably (Amini et al., 2014), it is important to differentiate between them. *Occupation* is defined as the broad categories of daily life activities in which people engage: activities of daily living, rest/sleep, education, work, play, leisure, and social participation (Amini et al., 2014). *Activities*, on the other hand, are the smaller actions or sets of tasks that occupations are constructed from (Polatajko et al., 2004). The term *purposeful activity* is used in this article to highlight that the activities under investigation are actions and sets of tasks with meaning and purpose, for example,

[1]Auckland University of Technology, New Zealand
[2]University of Wollongong, New South Wales, Australia

Corresponding Author:
Julie M. Collis, School of Clinical Sciences, Auckland University of Technology, 90 Akoranga Drive, Northcote, Auckland 0627, New Zealand.
Emails: julie.collis@aut.ac.nz

Table 1. Search Terms and String Used in the Review.

Intervention	Meaningful occupation, activity or task Purposeful activity Therapeutic occupation Occupationally embedded exercise Materials-based occupation Functional task Added purpose
Outcome	Performance Motor control Motor skill Quality of movement or motion Kinematic Quality or analysis of reach
Search string used for all four database searches	("meaningful occupation*" OR "meaningful activit*" OR "meaningful task*" OR "therapeutic occupation*" OR "occupation* embedd*" OR "materials based occupation*" OR "functional task*" OR "purposeful activit*" OR "add* purpose") AND (performance OR "motor control" OR "motor skill" OR "quality of movement" OR "quality of motion" OR kinematic OR "quality of reach" OR "analysis of reach")

using chopsticks or slicing vegetables, as opposed to broader *occupations*.

Approaches that use purposeful activities and occupations therapeutically have demonstrated beneficial effects on impairment and functional outcomes for individuals with upper extremity disorders (Weinstock-Zlotnick & Mehta, 2018). Therapists have been challenged to make meaningful occupations part of routine injury rehabilitation (Dy & Yancosek, 2017; Mehta et al., 2011) yet little is known about the mechanisms by which activities and occupations operate. It has been asserted that occupation-based interventions may be more effective than exercise alone because they: (a) promote self-efficacy, motivation, and engagement in rehabilitation; (b) promote greater dosage of motion; (c) preserve sensorimotor function; and (d) yield differences in motor performance from those seen during nonpurposeful tasks such as exercise (Colaianni & Provident, 2010; Dy & Yancosek, 2017; Hétu & Mercier, 2012; Mehta et al., 2011). For clarity, *motor performance* is defined here as the observable production of a voluntary action or motor skill (Schmidt & Wrisberg, 2008), and operationalised as both the quantity and quality of movement including movement duration, repetitions, range, speed, and smoothness.

Research in healthy and neurologically impaired populations suggests there is superior motor performance in the upper and lower extremity, when movement is embedded within purposeful activities, compared with movements performed under rote or purposeless conditions (Hétu & Mercier, 2012; Lin et al., 1997). There are no known reviews however, that investigated the influence of purposeful activities on motor performance after upper extremity musculoskeletal injury. Understanding causal mechanisms would elucidate theoretical foundations and be useful in informing the development of interventions that capitalize on the strengths of purposeful activities in promoting movement.

The UK Medical Research Council describes the first phase of complex health intervention development as identifying existing evidence and theoretical models (Craig et al., 2013). A broad-based systematic review that evaluates various study designs and populations contributes to this knowledge base (Squires et al., 2013). Other systematic reviews such as those by Weinstock-Zlotnick and Mehta (2018) and Bruder et al. (2017) have reviewed the efficacy of occupation and exercise interventions. This systematic review differs by focussing on the causal mechanisms of purposeful activities on movement, and the contexts in which they might occur. This systematic review therefore aimed to investigate the influence of purposeful activities on motor performance of the upper extremity in healthy and musculoskeletal injury populations.

Method

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) recommendations were followed (Moher et al., 2015; see supplementary file). The study protocol was registered on PROSPERO (CRD42019135666). In November 2018, the primary author (JC) searched Medline and CINAHL Complete (via EbscoHost) and Emcare and AMED (via Ovid) to identify studies that investigated the effect of purposeful activity on motor performance. A series of preliminary searches were undertaken to identify terms used before "occupation" gained widespread use. Table 1 details the final search terms and string. Results were exported to EndNote™ X8, citations combined and duplicates removed. Inclusion criteria are detailed in Table 2. A lower age limit of 16 years was set to capture older studies with a younger delineation of adulthood than the currently accepted age of 18 years. Titles and abstracts were reviewed by (JC) to eliminate studies not meeting the inclusion criteria. Reference lists and citations were screened to identify missed studies. Next, two authors (JC and VW) screened the full-texts of remaining articles to reach a consensus on articles to include.

Data were extracted from the studies by the primary author (JC) using a template including: author and date of

Table 2. Inclusion and Exclusion Criteria for Included Studies.

Inclusion criteria
- Adults aged ≥16 years
- Healthy or with an upper extremity musculoskeletal condition
- Published between 1980 and 2018
- Evaluation of at least one motor performance variable for the upper extremity
- Compared activity or occupation with meaning or purpose against task without meaning or purpose, simulated activity, rote exercise or movement repetition
- Published in English
- Original experimental research of any design

Exclusion criteria
- Neurological disorder
- Unpublished theses
- Systematic or narrative reviews, position papers
- Conference proceedings or reports

publication, study design, population size, participant characteristics, interventions or conditions, and results. In studies with healthy and neurological participants, data were reported for the healthy cohort only. For the purposes of clarity, nomenclature for groups and conditions were standardized across studies. The term *purposeful activity* was used to refer to an activity or occupation with purpose; *simulated activity*, where the activity was performed in a nonpurposeful manner, and *exercise* for movements performed for the purpose of exercise alone. Motor performance outcomes were reported as mean differences between conditions or groups. Effect sizes were calculated for individual outcomes, on the difference between condition or group, according to Hedges g, where 0.2, 0.5, and 0.8 indicates a small, medium, and large effect, respectively (Cooper et al., 2019). Meta-analysis was not conducted due to the disparate nature of design and purpose, and moderate quality of the studies.

Risk of bias in the included studies was assessed by the primary author (JC) using a modified version of the Downs and Black Quality Index (Downs & Black, 1998). The index is suitable for evaluating group and crossover studies and has good intra- and inter-rater reliability (r = .88 and .75, respectively) (Downs & Black, 1998). The index evaluates methodological quality of reporting, external quality, internal validity, and power. Questions not relevant to the included study designs were excluded, similar to other systematic reviews that included cross-over trials (Burdon et al., 2017). Scoring was modified from 0–28 to 0–20 where 20 represents studies of the highest quality. A random selection of studies (n = 6) were independently scored by another author (EM) to check agreement between assessors. Where scoring differed, consensus was reached through discussion.

Results

The study selection process is detailed in Figure 1. Twenty-one studies were selected for inclusion in the review. There were 831 participants in total, with an age range of 16 to 81 years. Sample sizes ranged from five to 146 participants. Only one study included a musculoskeletal injury population. In that study, King (1993), recruited 146 patients from a hand therapy clinic, but did not provide details of injury characteristics. Seventeen studies used a randomized crossover design and the remaining were group design. In all studies, random assignment was used for sequence or group allocation.

The quality assessment scores are shown in Table 3. Six studies were graded by two authors (JC and EM). Agreement was 97.5% so further comarking was not performed. The mean score was 13.6/20, with a range of 8 to 18. Recruitment showed evidence of bias in 16 studies. Blinding to the interventions was not possible in any study, but all participants were blinded to hypotheses. In the majority of studies (19/21), it is unclear whether assessors were blinded to the results until completion of data analysis. Randomization occurred in all studies; only three studies reported a power analysis for sample size. Analysis of variance was conducted in all 17 crossover trials to test for hypotheses and order effects. Risk of carryover effect was deemed to be low in these studies as counterbalancing was used to control for carryover and sequencing effects. With the exception of two studies (Ross & Nelson, 2000; Wu et al., 1998), the condition order had no effect on outcomes. Difference in group or condition means and standard deviations were reported for dependent variables in all studies. No study defined a primary outcome or reported confidence intervals.

Purposeful Activities and Motor Performance Outcomes

Characteristics of the studies and main results are presented in Table 4. The purposeful activities used in the studies included: personal care (Taylor et al., 2018); writing (Ross & Nelson, 2000; Wu et al., 1994); eating (Hall & Nelson, 1998); using chopsticks (Ma et al., 1999; Rice et al., 2009); reaching for candy (Sackaloo et al., 2015), a mug (Holubar & Rice, 2006; Rice et al., 2009), a bell (Lin et al., 1998; Morton et al., 1992) or a magazine (Rice & Renock, 2006); meal preparation tasks (e.g., slicing vegetables or making cookies) (Fasoli et al., 2002; Hoppe et al., 2008; Miller & Nelson, 1987; Rice et al., 1999; Wu et al., 1998); woodwork or handcrafts (Bakshi et al., 1991); and board or computer games, throwing darts or ping-pong (Kehoe & Rice, 2016; King, 1993; Steinbeck, 1986; Wagner et al., 1995).

The range of motor performance outcomes measured varied. Outcomes for quantity of movement were limited to numbers of repetitions, duration of performance, and range of movement. Quality of motion was evaluated by velocity, time taken to complete a movement, reaction time, movement units, and displacement. Quantity metrics were reported in eight and quality in 13 studies. Motor performance was measured by three-dimensional (3D) motion capture systems, electrogoniometry, computer software or by manual counting or stopwatch. The majority of studies (17/21) found better

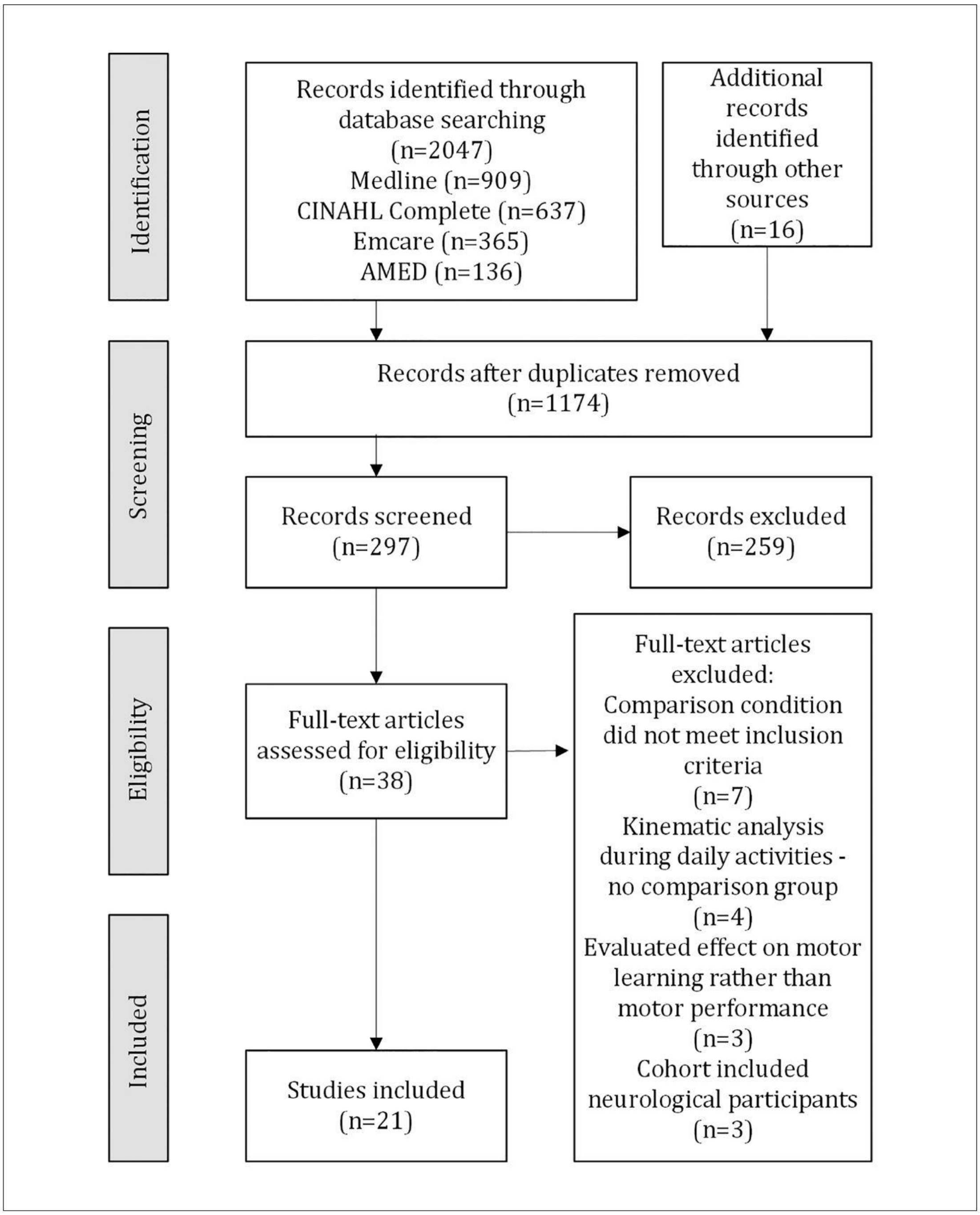


Figure 1. PRISMA flow diagram.
Note. PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analysis.

Table 3. Scoring of the Downs and Black Quality Index.

	Reporting								External validity		Internal validity (bias)					Internal validity (confounding)			Power	
Question	1	2	3	4	5	6	7	10	11	12	14	15	16	18	20	21	23	25	27	Score
Bakshi et al. (1991)	1	1	1	0	1	1	0	1	0	0	0	0	1	1	1	1	1	0	0	11
Fasoli et al. (2002)	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	15
Hall and Nelson (1998)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	14
Holubar and Rice (2006)	1	1	1	1	2	1	1	1	1	1	0	0	1	1	1	1	1	1	1	18
Hoppe et al. (2008)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	0	13
Kehoe and Rice (2016)	1	1	1	1	2	1	1	1	1	0	0	0	1	1	1	1	1	1	1	17
King (1993)	1	1	0	1	0	1	1	1	0	0	0	0	1	0	0	1	0	0	0	8
Lin et al. (1998)	1	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	13
Ma et al. (1999)	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	15
Miller and Nelson (1987)	1	1	0	1	0	1	1	1	0	0	0	0	0	1	0	1	1	1	0	10
Morton et al. (1992)	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	1	1	0	0	10
Rice et al. (1999)	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0	13
Rice et al. (2009)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	14
Rice and Renock (2006)	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	16
Ross and Nelson (2000)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	14
Sackaloo et al. (2015)	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	0	15
Steinbeck (1986)	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	0	0	14
Taylor et al. (2018)	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	15
Wagner et al. (1995)	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	0	0	12
Wu et al. (1998)	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	15
Wu et al. (1994)	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	13

Note. Modified Downs and Black Quality Index: questions 8, 9, 13, 17, 19, 22, 24, and 26 were removed as not relevant to the study designs in this review.

motor performance in favor of purposeful activity in at least one outcome. In one low-quality study (Wagner et al., 1995), the data were in favor of exercise, and in two low-quality studies (Bakshi et al., 1991; Morton et al., 1992) no differences were observed between groups for any outcome. Many studies found differences for some performance variables and no differences for others.

Quantity of Motion: Repetitions, Duration, and Arcs of Motion

Seven studies measured the number of repetitions completed during a given time frame or until fatigue. In four of these studies (Hoppe et al., 2008; King, 1993; Miller & Nelson, 1987; Steinbeck, 1986), small to medium effects were found for purposeful activity. Participants performed a greater number of repetitions in purposeful activity groups, with differences reaching statistical significance except in the study by Miller and Nelson (1987). Only three studies measured duration of performance, with participants allowed to work for as long as desired (Hoppe et al., 2008; Miller & Nelson, 1987) or until perceived exertion reached "very hard" (Morton et al., 1992). The study by Hoppe et al. (2008) showed that participants who stirred cookie dough, performed for longer periods of time than when stirring a concealed bowl of an unknown substance. Similarly, Miller and Nelson (1987) found longer duration of performance in their purposeful activity condition. Differences were nonsignificant in that study, but with a large effect size. Conversely, no difference in performance duration was found by Morton et al. (1992). The study by Taylor et al. (2018) was the only study that evaluated joint range of motion. Greater arcs of shoulder and wrist motion were required to perform functional activities than simulated tasks, for most of the activities evaluated.

Quality of Motion: Speed, Movement and Reaction Time, Movement Units, Displacement

Thirteen studies measured various aspects of velocity, with peak velocity being measured most frequently (11 studies). Peak velocity was significantly higher in three studies, lower in four, and equal in the remaining studies. Ten studies measured percentage of movement time to reach or maintain peak velocity, but only five studies found statistically significant differences. Movement time was measured in 13 studies, with eight studies reporting quicker movement during the purposeful activity condition (Fasoli et al., 2002; Holubar & Rice, 2006; Lin et al., 1998; Rice et al., 2009; Ross & Nelson, 2000; Sackaloo et al., 2015; Wu et al., 1994) or virtual reality (Kehoe & Rice, 2016). Large effects were demonstrated in two of these studies (Fasoli et al., 2002; Kehoe

Table 4. Study Characteristics and Outcomes.

Study	Design and participants	Interventions	Outcomes	Results
Bakshi et al. (1991)	Randomized, counterbalanced, repeat measures Two-factor experiment Healthy adult students (n = 20) M:F = 0:20 Mean age: 23 years	PA: eight handcraft or woodwork activities SA: same activities performed as a movement repetition Participants selected most and least preferred occupations and performed them under both conditions (PA and SA) in random order for 10 min	Number of repetitions during 10-min session counted manually Participants rated perceived exertion on an ordinal scale (from very, very light to very, very hard) Heart rate measured with a wireless heart monitor and blood pressure measured manually	No significant difference, between PA and SA groups in number of repetitions performed No. of repetitions (PA vs SA): Most preferred 63.3 ± 33.7 versus 82.9 ± 39.1, g = −0.54 Least preferred 63.1 ± 31.9 versus 84.4 ± 43.6, g = −0.55
Fasoli et al. (2002)	Randomized, counterbalanced, repeat measures Healthy participants (n = 5) M:F = 1:4 Mean age: 58 years	PA: slicing bread, slicing tomato, stirring cup of coffee, hammering a nail. SA (three conditions): same tasks performed with limited or no materials/tools	MT (s) PV (mm/s) MUs D (mm) Measured by a motion capture system	Significantly lower PV and less D for all tasks in favor of PA MT faster for slicing bread, slicing tomato and hammering, and fewer MUs for hammering All other data were nonsignificant Data for hammering PA versus SA: MT 1.45 ± 0.41 versus 1.99 ± 0.44, g= 1.15 PV 67.63 ± 25.57 versus 1,271.49 ± 542.76, g = 2.83 MUs 6.10 ± 0.22 versus 7.00 ± 0.50, g = 2.10 D 193.17 ± 96.56 versus 1,153.00 ± 620.08, g = 1.95
Hall and Nelson (1998)	Randomized, counterbalanced, repeated measures College students (n = 47) M:F = 0:47 Mean age: 22 years	PA: eating applesauce with a spoon SA (two conditions): same task performed with limited or no materials/tools	MT (s) PV (cm/s) MUs D (cm) Measured by a four-camera motion capture system	Significantly longer MT and lower PV in favor of PA Significantly greater MUs against PA. No difference for D PA versus SA: MT 2.75 ± 0.35 versus 2.00 ± 0.36, g = 2.10 PV 59.3 ± 12.6 versus 80.2 ± 14.7, g = 1.51 MUs (from start to mouth) 13.7 ± 3.6 versus 4.5 ± 3.0, g= −2.75 D 46.3 ± 7.2 versus 49.0 ± 11.1, g = −0.29
Holubar and Rice (2006)	Randomized, counterbalanced, repeated measures Healthy adults (n = 32) M:F = 0:32 Mean age: 44 years	Reaching and placing own mug or mug owned by researcher in a lab or at home	MT (s) PV (°/s) Percentage of MT at PV MUs D (°) Measured by an electrogoniometer across the elbow	MT significantly faster when reaching for own mug versus researcher's mug regardless of location: 0.96 ± 0.21 versus 1.00 ± 0.22, g = 0.18, at home; 0.94 ± 0.23 versus 0.98 ± 0.20 at lab, g = 0.18 Fewer MUs for participants reaching for their own mug in the lab compared with at home: 3.06 ± 1.72 versus 3.63 ± 2.46, g = 0.27 No other differences observed for mug ownership or location in remaining outcomes
Hoppe et al. (2008)	Randomized, counterbalanced, repeated measures College students (n = 30) M:F = 0:30 Mean age: 22 years	PA: stirring cookie dough. Environment enriched to replicate purposeful activity of making cookies SA: stirring an unknown substance in a covered bowl	Number of repetitions Duration of performance Repetitions counted by researcher, duration recorded by a stopwatch	PA group performed a significantly greater number of repetitions, 80 ± 59 versus 62 ± 40, p < .004, g = 0.35, for a significantly longer time, 125 ± 80 versus 109 ± 87 s, p < .012, g= 0.19
Kehoe and Rice (2016)	Randomized, counterbalanced, repeated measures Healthy adults (novice dart players) (n = 34) M:F = 15:19 Mean age: 26 years	PA: throwing darts at dart-board VR: throwing virtual darts at a virtual dartboard SA: throwing imaginary darts at a blacked-out dartboard	D (cm) PV (m/s) MT (s) Percentage of MT to PV MUs MA (largest distance between thumb and index finger during the throw) Measured by an eight-camera motion capture system, X-box 360 and Kinect sensor	Significant differences for D, PV MT, percentage of MT to PV and MA in favor of PA or VR: D (PA vs. SA) 242.38 ± 85.28 versus 258.22 ± 128.08, g = 0.14 D (VR vs. SA) 168.91 ± 84.91 versus 258.22 ± 128.08, g = 0.81 PV (PA vs. SA) 3.75 ± 1.15 versus 2.47 ± 0.93, g = 1.21 MT (VR vs. SA) 0.40 ± 0.24 versus 0.63 ± 0.32, g = 0.80 Percentage of MT to PV (VR vs. SA) 24.14 ± 14.09 versus 34.72 ± 19.59 MA (PA vs. VR) 0.11 ± 0.018 versus 0.08 ± 0.02, g = 1.56 MA (PA vs. SA) 0.11 ± 0.018 versus 0.098 ± 0.025, g = 0.54 No differences found for MUs
King (1993)	Counterbalanced, repeated measures Hand therapy patients (n = 146) M:F = 84:62 Age range: 16–78 years	PA: missile computer game where participant could use grip or pinch device to stop missiles Ex: squeeze the grip or pinch device	Number of repetitions Measured by a computer program	Significant differences between the groups in favor of PA. Mean reps/3 min, PA vs. Ex: Grippers 237.24 ± 109.5 versus 170.7 ± 85.96, p < .001, g= 0.67 Pinchers 240.5 ± 101.51 versus 203.2 ± 98.16, p < .05, g= 0.37

(continued)

Table 4. (continued)

Study	Design and participants	Interventions	Outcomes	Results
Lin et al. (1998)	Randomized, counterbalanced, repeated measures Healthy adults (*n* = 24) M:F = 8:16 Mean age: 24 years	PA: reaching for and pressing the lever of a desk bell to make it ring SA: same task but bell did not ring. Control: reaching forwards and bisecting a line on a piece of paper	MT (s) PV (mm/s) Percentage of MT at PV Measured by a three-camera motion capture system	Significant difference for MT and PV in favor of PA. PA versus control: MT 0.71 ± 0.13 versus 0.78 ± 0.21, g = 0.39 PV 1,259.2 ± 199 versus 1,198.9 ± 228.6, g = 0.28 No difference for percentage of MT at PV
Ma et al. (1999)	Healthy adults without experience using chopsticks (*n* = 40) M:F = 12:28 Mean age: 24 years	PA: pick up and eat cheese with chopsticks. SA: pick up eraser and bring it to the mouth. Both conditions assessed during a learning phase and then as immediate motor performance 24 hr later	Successful completion of task MT (s) D (mm) PV (mm/s) Measured by three-camera motion capture	Success rate significantly greater in the PA group versus SA group: 0.70 ± 0.17 versus 0.59 ± 0.20, g = 0.59. No differences in MT, PV or D between the conditions
Miller and Nelson (1987)	Randomized, repeat measures Healthy adults (*n* = 30) M:F = 0:30 Age not provided	PA: stirring a substance in a concealed bowl to make cookies. Vanilla added to mixture and fresh cookies in the oven to simulate baking environs. SA: as above but environment not augmented	Repetitions Duration of performance Manual counts of repetitions, stopwatch used for recording duration	Nonsignificant differences in favor of PA. PA versus SA: Repetitions: 103.3 ± 67.3 versus 77.07 ± 54.2, p = .052, g = 0.42 Duration: 233.4 ± 169.3 versus 141.07 ± 87.4, g = 0.67
Morton et al. (1992)	Randomized, repeated measures Healthy adults (*n* = 30) M:F = 15:15 Mean age: 45 years	PA: pushing lever on a weight-box device to ring a bell Ex: pushing lever on weight-box (no bell)	Repetitions Duration of performance Manual counts of repetitions, stopwatch used for recording duration	No significant differences between PA and Ex groups for number of repetitions or duration. PA versus Ex (mean values of three trials): Repetitions: 169.37 ± 103.03 versus 186.53 ± 75.15, g = −0.19 Duration: 175.38 ± 103.18 versus 191.73 ± 72.1, g = −0.15
Rice et al. (1999)	Randomized, counterbalanced, repeated measures Healthy adults (*n* = 39) M:F = 0:39 Mean age: 30 years	PA: grasping a familiar labeled can of tomato soup from the bench and placing on a shelf SA: grasping and placing an unlabelled can of soup Ex: grasping and placing a lump of clay (weight and shape matched)	MT (s) MUs D (°) Measured by an electrogoniometer placed on right elbow	Significantly fewer MUs (smoother movement) in the PA versus Ex: 59.85 ± 19.79 versus 66.03 ± 24.10, g = 0.28 Significantly less D in SA versus Ex: 492.42 ± 151.11 versus 526.61 ± 99.01, g = 0.27 No difference in MT between the groups
Rice et al. (2009)	Randomized, counterbalanced, repeated measures two-factor experiment with repeated measures on one factor Healthy adults (*n* = 59) M:F = 12:28 Age range: 18–45 years	PA: opening a cupboard door, reaching for and placing a cup on a shelf, immediate or prolonged exposure (transparent or opaque door) SA: as above with a lump of clay (shape and weight matched)	MT (s) PV (mm/s) MV (mm/s) Percentage of MT to PV MUs D (mm) Measured by a four-camera motion capture system	No significant differences between PA and SA for immediate exposure condition When participants had prolonged visual exposure to objects there was faster movement, higher mean PV, quicker time to PV and fewer MUs PA versus SA: MT 0.57 ± 0.24 versus 0.64 ± 0.21, g = 0.31 MV 669.00 ± 795.45 versus 349.34 ± 480.01, g = 0.48 percentage of MT to PV 0.56 ± 0.26 versus 0.45 ± 0.25, g = 0.43 MUs 2.21 ± 1.78 versus versus 2.76 ± 1.81, g = 0.30
Rice and Renock (2006)	Randomized, counterbalanced, repeated measures Healthy adults (*n* = 43) M:F = 0:43 Age range: 22–62 years	PA: reaching for a magazine in three different conditions; most preferred, neutrally preferred or least preferred magazine	MT (s) PV (°/s) Percentage of MT to PV MUs D (°) Measured by elbow electrogoniometer	No significant differences on any DV excepting slower MT, and greater MUs, for neutrally preferred versus least preferred magazines: MT 1.31 ± 0.95 versus 0.95 ± 0.43, g = −0.43 MU 9.09 ± 6.72 versus 6.40 ± 3.65, g = 0.56
Ross and Nelson (2000)	Randomized, counterbalanced, repeated measures Healthy adults (*n* = 60) M:F = 0:60 Mean age: 22 years	PA: pick up pencil and prepare to write name in normal manner SA: pretend to pick up a pencil and prepare to write name Ex: reaching forward movement in equidistance and height as PA condition	RT (s) MT (s) MUs D (cm) PV (cm/s) Percentage of MT to PV EV (cm/s) Measured by four-camera motion capture system	Significantly better outcomes in PA than SA or Ex for all DVs (faster RT and MT, fewer MUs, lower D, PV and EV) For PA versus Ex conditions: RT 0.416 ± 0.11 versus 0.429 ± 0.11, g = 0.12 MT 0.526 ± 0.08 versus 0.550 ± 0.14, g = 0.21 MUs 1.10 ± 0.24 versus 1.26 ± 0.35, g = 0.53 D. 43.5 ± 4.7 versus 48.4 ± 6.7, g = 0.84 PV 113.7 ± 17.0 versus 123.0 ± 17.7, g = 0.53 percentage of MT to PV 0.579 ± 0.08 versus 0.647 ± 0.11, g = 0.70 EV 55.5 ± 12.8 versus 81.1 ± 22.9, g = 1.37

(continued)

Table 4. (continued)

Study	Design and participants	Interventions	Outcomes	Results
Sackaloo et al. (2015)	Randomized, counterbalanced, repeated measures Healthy adults (n = 40) Mean age: 23 years Gender not reported	PA: reaching for seven different types of candy ranked by participants from most to least preferred (three conditions: most, neutral and least preferred) Candy placed in front of participant; candy reached for, grasped and brought back to a marked position on table	MT (s) PV (mm/s) Percentage of MT to PV MUs Measured by a four-camera motion capture system	Significantly faster movement time, and fewer MUs, in the most preferred versus least preferred conditions MT 0.73 ± 0.26 versus 0.82 ± 0.23, p = .003, g = 0.36 MUs 2.89 ± 2.80 versus 3.77 ± 2.00, p = .001, g = 0.36 No significant differences for PV and time to PV between most, neutral or least preferred conditions
Steinbeck (1986)	Randomized, counterbalanced, repeated measures Healthy adults (n = 30) M:F = 15:15 Mean age: 19 years	PA: ping-pong game; squeezing rubber bulb to above specified track Ex: squeezing a rubber ball for Ex (no game) Both conditions performed to perceived point of "working somewhat hard"	Number of repetitions Manual count of repetitions	Significantly greater number of repetitions in the PA versus Ex groups: 105.67 ± 33.55 versus 95.50 ± 32.45, p= .05, g = 0.30
Taylor et al. (2018)	Randomized, counterbalanced, repeated measures Healthy adults (n = 14) M:F = 8:0 Mean age: 22 years	PA: five purposeful activities (washing armpit, eating, combing hair, retrieving bottle from a shelf, perineal care) SA: performing the equivalent activities as a movement (e.g., touching contralateral armpit, touching the mouth or back of head)	Maximum and minimum joint ROM (°) Joint angles (°) Movement patterns (mean from 0% to 100% of movement cycle for each task) Movement variability (°) Measured by an 11-camera motion capture system	Thoracic ROMs were significantly greater in PA versus SA. Shoulder elevation and internal/external rotation for perineal care 90° versus 79° and 77° versus 63° respectively; shoulder elevation 81° versus 68° for combing hair, and 129° versus 107° for retrieving object from shelf. Forearm rotation showed no differences between either condition for any task. Wrist ROMs were greater for PA versus SA for all tasks, except washing armpit. Few differences in intrasubject movement variability between conditions
Wagner et al. (1995)	Randomized, repeated measures Healthy adults (n = 45) M:F = 45:0 Mean age: 25 years	PA: moving a cork ball on a board using air squeezed from a rubber bulb as a game for 2 min with another person present. Ex (two conditions): squeeze a rubber bulb as Ex for 2 min, with another person present or alone	Number of repetitions Manual count of repetitions	Significantly greater repetitions in favor of Ex. PA versus Ex: 270.13 ± 61.15 versus 341.53 ± 53.83, g = −1.23
Wu et al. (1998)	Randomized, counterbalanced, repeat measures Healthy participants (n = 25) (14 stroke; results not reported here) M:F = 6:17 Mean age: 63 years	PA: reaching forward and pushing down on a handle to chop a fresh mushroom SA: reaching forward and pushing down on a concealed handle (no mushroom)	MT D PV Percentage of MT at PV MUs Measured by a two-camera motion capture system	Findings were nonsignificant or not in support of PA vs. SA: MT 0.51 ± 0.13 versus 0.47 ± 0.10, g = −0.34 D 398.59 ± 52.72, versus 387.62 ± 44.4, g = −0.22 PV 1,260.79 ± 304.64 versus 1,272.18 ± 290.38, g = 0.04 Percentage of MT at PV 42.35 ± 7.67 versus 44.53 ± 7.27, g = 0.29 MUs 0.73 ± 0.22 versus versus 0.72 ± 0.24, g = −0.04
Wu et al. (1994)	Randomized, counterbalanced, repeated measures Healthy physiotherapy or biomedical students (n = 37) M:F = 0:37 Mean age: 21 years	PA: pick up a pencil from a pencil holder and prepare to write name SA: pick up an imaginary pencil and pretend to prepare to write name Ex: reach forward movement in equidistance and height as PA	RT (s) MT (s) MUs D (cm) PV (mm/s) Percentage of MT at PV Measured by a three-camera motion capture system	Significant differences in favor of PA for RT, MT, MUs and D PA vs. Ex: RT 0.391 ± 0.068 versus 0.434 ± 0.075, g = 0.59 MT 0.976 ± 0.154 versus 1.062 ± 0.161, g = 0.54 MUs 0.891 ± 0.405 versus 1.292 ± 0.446, g = 0.93 D 41.331 ± 5.556 versus 47.551 ± 7.679, g = 0.92 PV and percentage of MT at PV were lower in the PA versus Ex condition: PV 1,214.332 ± 505.968 versus 1,610.311 ± 963.354, g = 0.51 Percentage of MT at PV 58.42 ± 16.15 versus 66.79 ± 20.72, g = 0.45

Note. Values are mean ± *SD* or as otherwise indicated. The statistic g refers to Hedges g for effect size, where 0.2 = small effect, 0.5 = medium effect, 0.8 = large effect and were calculated on the difference between condition or group. M = male; F = female; PA = purposeful activity; SA = simulated activity; MT = movement time; PV = peak velocity; MU = movement unit; D = displacement; VR = virtual reality; MA = maximum aperture; Ex = exercise; MV = mean velocity; DV = dependent variable; RT = reaction time; EV = end velocity; ROM = range of movement.

& Rice, 2016). A large and significant effect for movement time was also reported by Hall and Nelson (1998) but in the opposite direction, of longer movement time. No difference was observed by Kehoe and Rice (2016) or Rice et al. (1999). Reaction time was measured by Ross and Nelson (2000) and Wu et al. (1998), and was faster during purposeful activity in both studies. Eleven studies measured movement units, an indicator of movement smoothness calculated by summing the number of times acceleration went from negative to positive to negative (Holubar & Rice, 2006; Kehoe & Rice, 2016). Seven of these studies showed small to medium effects of purposeful activity in producing fewer movement units (Rice et al., 1999; Ross & Nelson, 2000; Wu et al., 1994), when participants used their own objects (Holubar & Rice, 2006), reached for preferred items during the experiment (Rice & Renock, 2006; Sackaloo et al., 2015), or were visually exposed to the objects for longer periods of time (Rice et al., 2009). Fasoli et al. (2002) demonstrated a large effect size for one of the four activities (hammering). Displacement was measured in 12 studies, with lower displacement an indication of more direct, controlled movement. In five of these studies, displacement was significantly lower in purposeful activity groups. For example, in the high-quality study by Kehoe and Rice (2016), throwing an actual dart showed less displacement than in a virtual reality dart game.

Discussion

This review was conducted to identify the influence of engaging in purposeful activities and occupations on upper extremity motor performance in healthy and musculoskeletal injury populations. The results provided evidence that purposeful activities had a beneficial effect on the quality and quantity of movement in healthy populations, distinct from simulated tasks, exercise repetitions or movement performed under artificial conditions. The findings suggested that when a person engaged in an activity or occupation equal or similar to that in everyday life, they were likely to perform more repetitions for longer periods of time. In addition, movement was more likely to be smoother, more controlled and performed more quickly. The findings of this review concur with results from reviews in predominantly neurological populations (Hétu & Mercier, 2012; Lin et al., 1997), that also found enhanced motor performance for movement embedded in familiar activities as opposed to arbitrary motion.

The body of evidence in this review was drawn from studies of moderate quality and conducted mainly in healthy populations. There was a paucity of research on the influence of purposeful activities in individuals with musculoskeletal injuries. Despite an extensive search, only one study (King, 1993) was located that included individuals with a musculoskeletal condition or injury. In that study King (1993) demonstrated significantly greater movement quantity in the activity group, but the study was of very low quality. Caution must be applied in generalizing the results from that study, as King did not report on the nature or characteristics of the participant's injuries. With respect to the quality of the studies in the review, concerns were noted with recruitment, reporting, blinding, validity of outcome measures, and statistical analyses that did not consider covariates. There was an overrepresentation of young participants, females and students, making generalizability to other healthy populations such as older adults or manual workers, difficult. Manual counting was used in six of the seven studies that measured repetitions (Bakshi et al., 1991; Hoppe et al., 2008; Miller & Nelson, 1987; Morton et al., 1992; Steinbeck, 1986; Wagner et al., 1995), leading to potentially inaccurate counting or inconsistencies in what constituted a repetition. Lack of study rigor indicated that the findings be interpreted with caution and highlighted a need for replication of this type of research in individuals with upper extremity injury.

Purposeful Activities and Occupations

A premise under investigation in this review is that purposeful activities and occupations elicit motor performance measurably different from nonpurposeful tasks or rote exercises. The purpose and meaning ascribed to activities and occupations is complex (Eakman et al., 2010), and was not evaluated in any of the studies. The degree to which the activities or occupations held purpose or meaning for participants was therefore unknown. Many of the activities in the studies could be considered repetitious and purposeless, such as ringing a bell, or placing a can or mug onto a shelf (Holubar & Rice, 2006; Lin et al., 1998; Rice et al., 1999). Even in the study by Bakshi and colleagues (1991) where activities were self-selected, choice was limited to eight activities and their perceived value was unknown. If an activity lacks value, an individual may not persevere for as long, put in equal amounts of effort or attend to the task with the same degree of focus, potentially lowering the quality and quantity of the movement produced. In future, research that evaluates movement during the performance of activities or occupations, it is recommended that the activities are: (a) self-selected; (b) performed in a naturalistic manner; (c) conducted in the participants' own environment; and (d) evaluated for meaning using tools designed for that purpose such as the Occupational Value-9 (Persson & Erlandsson, 2010), or the Meaningful Activity Participation Assessment (Eakman et al., 2010).

Several studies investigated the relative effect that objects and materials have on motor performance during an occupation (Holubar & Rice, 2006; Rice & Renock, 2006; Sackaloo et al., 2015). In those studies, movement speed and smoothness were enhanced in participants who reached for a personally owned or preferred object. This premise has been corroborated by Hétu and Mercier (2012), who found that adding an object to a motor task enhanced quality of movement. The results suggest that clinicians may be able to enhance motor performance by having patients use their own materials and objects during therapy, for example, by putting on items of clothing or playing a preferred game. Therapists could observe movement during performance of purposeful activities and modify the activity or movement parameter to achieve the desired motor outcome.

Motor Performance Outcomes

Motor performance outcomes varied across studies, and none were measured by all authors. With respect to quantity or dosage of motion, small to medium effects were observed for purposeful activities and occupations. For the most part, participants performed more repetitions and for longer periods of time, when performing purposeful activities. In studies where duration of performance was foreshortened, it is possible that the activity itself was insufficiently motivating to persevere for longer. As an example, the activity in the study by Morton et al. (1992) involved the pushing of a lever in a weight box apparatus, either to ring a bell (activity with purpose) or as exercise (without purpose). Although participants in the purpose group found the bell-ringing fun, this did not result in longer duration of performance compared with the group who had no bell. The nature of activities and occupations are that they involve purpose, meaning and occur within the context of daily life (Molineux, 2010). The activity in Morton's study did not relate to any purposeful end goal, lacked meaning and was performed in an artificial research environment, and these factors may have accounted for the lack of perseverance observed in both groups. The study by Taylor et al. (2018) was the only study to evaluate range of motion during the performance of functional tasks. Those authors showed that participants used greater arcs, and therefore higher overall volume of motion, when performing tasks in a naturalistic manner rather than as simulated motions.

The findings of enhanced movement quantity demonstrate opportunity for therapists to use purposeful activities in more strategic ways. Wrist and finger stiffness is a common complication after injury, and occurs, for example, in up to 20% of patients with surgery of distal radial fracture (Egol et al., 2014). Range of movement exercises are used to promote movement, but have variable rates of adherence and may not achieve the desired dosage of motion (Bassett, 2003). The findings from this review can only be applied to healthy participants but point to the potential of purposeful activities and occupations in augmenting the amount of movement volume.

Quality of motion was evaluated by a range of kinematic variables where faster reaction and movement times, higher peak velocity, less displacement and fewer movement units indicate greater movement efficiency and control (Kehoe & Rice, 2016). Reaction and movement times were faster during purposeful activity conditions in the majority of studies that measured those outcomes. Although the magnitude of effect was predominantly small to medium, this may indicate that the familiarity of movement during purposeful activities requires less focus and attention than nonpurposeful tasks. A large effect for purposeful activity on movement time was found by Fasoli et al. (2002), but as the study only sampled five participants this may represent an inflated effect size. Velocity metrics included peak velocity and percentage of movement time to peak velocity. Significant differences were found in a majority of studies. In most cases, higher peak velocity was assumed to represent greater movement efficiency and skill (Kehoe & Rice, 2016; Lin et al., 1998). The opposite was hypothesized in some cases, in that movement executed more slowly with lower peak velocity allowed for greater control and was an indication of more skilled motion (Fasoli et al., 2002; Hall & Nelson, 1998). The differing outcomes for peak velocity may be related to the differing demands of the task (e.g., throwing a dart vs. slicing bread), where one task inherently requires greater speed over another. This highlights the need to further evaluate the differential effect of various activities and occupations on motor performance metrics.

Smoothness and coordination were measured by the number of times that acceleration and deceleration occurred in succession during a movement (movement units) (Rice & Renock, 2006). Generally, fewer movement units are associated with smoother motion (Holubar & Rice, 2006). In this review, a majority of studies found fewer movement units when participants were engaged in a purposeful activity, particularly where familiar or preferred objects were used. The estimated effects were generally small to medium, but if a similar finding were established in clinical populations, purposeful activities have potential for helping to restore smooth, dextrous motion after injury.

Limitations and Future Directions

This review brought together a body of work that has not previously been examined in the musculoskeletal field. Although a large number of studies were identified, the difficulty of locating all studies must be acknowledged due to the range of terms used for occupation, particularly in older studies. Other limitations of this review include only one reviewer screening the titles and abstracts during the initial screening phase, and the inclusion of only one study in a population with musculoskeletal injury. The applications of the findings to clinical practice must therefore be regarded as suggestions only. The findings nonetheless represent best available evidence at this time and highlight the need for further research in clinical populations.

Future research should investigate the influence of activities and occupations in upper extremity pathologies and in isolated joints of the upper extremity. Activities and occupations investigated should be those selected by participants as having meaning and purpose. Researchers are challenged to conduct investigations in the environments in which participants perform daily occupations. This is becoming increasingly possible with advances in wearable technologies and field motion capture systems. Evaluating discrete activities and occupations linked to specified motor performance impairments will help to elucidate which occupations can be used to target identified problems; for example, loss of finger dexterity, wrist extension loss, or difficulties with initiating finger flexion.

Conclusion

This review found evidence from multiple randomized studies that for healthy adults, engagement in purposeful activities will generally result in greater quantity and quality of movement than simulated activities or movement performed without purpose. Occupation-based interventions are increasingly being advocated in the musculoskeletal literature for treating motor impairments, yet the mechanisms by which they operate are not well-understood. This review adds evidence to the premise that purposeful activities elicit movement in measurably different ways from nonpurposeful tasks. Investigating the mechanisms of action of purposeful activities and occupations after upper extremity injuries would elucidate whether motor performance is influenced similarly in injured individuals. These data would provide a robust foundation on which to develop interventions based on the strengths of movement embedded in purposeful activities and occupations.

Authors' Note

This material has not been previously presented in any forum including symposia or conferences. A manuscript editor, Audrey Holmes, employed by the Auckland University of Technology, provided editorial support for an early version of this manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Julie M. Collis https://orcid.org/0000-0002-6560-6287

References

Amini, D. A., Kannenberg, K., Bodison, S., Chang, P. F., Handley-More, D., McElroy, A., . . . Lieberman, D. (2014). Occupational therapy practice framework: Domain & process 3rd edition. *American Journal of Occupational Therapy*, *68*, S1–S48. https://doi.org/10.5014/ajot.2014.682006

Bakshi, R., Bhambhani, Y., & Madill, H. (1991). The effects of task preference on performance during purposeful and nonpurposeful activities. *American Journal of Occupational Therapy*, *45*, 912–916. https://doi.org/10.5014/ajot.45.10.912

Bassett, S. F. (2003). The assessment of patient adherence to physiotherapy rehabilitation. *New Zealand Journal of Physiotherapy*, *31*, 60–66.

Bialocerkowski, A. E. (2002). Difficulties associated with wrist disorders-A qualitative study. *Clinical Rehabilitation*, *16*, 429–440. https://doi.org/10.1191/0269215502cr516oa

Bruder, A. M., Shields, N., Dodd, K. J., & Taylor, N. F. (2017). Prescribed exercise programs may not be effective in reducing impairments and improving activity during upper limb fracture rehabilitation: A systematic review. *Journal of Physiotherapy*, *63*, 205–220. https://doi.org/10.1016/j.jphys.2017.08.009

Burdon, C., Spronk, I., Cheng, H. L., & O'Connor, H. (2017). Effect of glycemic index of a pre-exercise meal on endurance exercise performance: A systematic review and meta-analysis. *Sports Medicine*, *47*, 1087–1101. https://doi.org/10.1007/s40279-016-0632-8

Chung, K. C., & Haas, A. (2009). Relationship between patient satisfaction and objective functional outcome after surgical treatment for distal radius fractures. *Journal of Hand Therapy*, *22*, 302–308. https://doi.org/10.1016/j.jht.2009.04.007

Colaianni, D., & Provident, I. (2010). The benefits of and challenges to the use of occupation in hand therapy. *Occupational Therapy in Health Care*, *24*, 130–146. https://doi.org/10.3109/07380570903349378

Cooper, H., Hedges, L., & Valentine, J. (Eds.). (2019). *The handbook of research synthesis and meta-analysis* (3rd ed.). Russell Sage Foundation. https://doi.org/10.7758/9781610448864.14

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2013). Developing and evaluating complex interventions: The new Medical Research Council guidance. *International Journal of Nursing Studies*, *50*, 587–592.

Downs, S. H., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *Journal of Epidemiology & Community Health*, *52*, 377–384. https://doi.org/10.1136/jech.52.6.377

Dy, L. B., & Yancosek, K. E. (2017). Introducing purposeful activity kits in a hand rehabilitation practice: Effects on clinical practice patterns and job satisfaction among occupational therapy practitioners. *Hand Therapy*, *22*, 3–12. https://doi.org/10.1177/1758998316657844

Eakman, A., Carlson, M., & Clark, F. (2010). The meaningful activity participation assessment: A measure of engagement in personally valued activities. *International Journal of Aging & Human Development*, *70*, 299–317. https://doi.org/10.2190/ag.70.4.b

Egol, K. A., Karia, R., Zingman, A., Lee, S., & Paksima, N. (2014). Hand stiffness following distal radius fractures. *Bulletin of the Hospital for Joint Diseases*, *72*, 288–293. https://doi.org/10.1016/s0363-5023(09)60100-3

Fasoli, S. E., Trombly, C. A., Tickle-Degnen, L., & Verfaellie, M. H. (2002). Context and goal-directed movement: The effect of materials-based occupation. *OTJR: Occupation, Participation and Health*, *22*, 119–128. https://doi.org/10.1177/153944920202200305

Hall, B. A., & Nelson, D. L. (1998). The effect of materials on performance: A kinematic analysis of eating. *Scandinavian Journal of Occupational Therapy*, *5*, 69–81. https://doi.org/10.3109/11038129809035732

Hétu, S., & Mercier, C. (2012). Using purposeful tasks to improve motor performance: Does object affordance matter? *British Journal of Occupational Therapy*, *75*, 367–376. https://doi.org/10.4276/030802212X13433105374314

Holubar, M. N., & Rice, M. S. (2006). The effects of contextual relevance and ownership on a reaching and placing task.

Australian Occupational Therapy Journal, *53*, 35–42. https://doi.org/10.1111/j.1440-1630.2006.00538.x

Hoppe, K. A., Miller, B. K., & Rice, M. S. (2008). Occupationally embedded exercise versus rote exercise and psychosocial response in college-aged females. *Occupational Therapy in Mental Health*, *24*, 176–191. https://doi.org/10.1080/01642120802055317

Karagiannopoulos, C., Sitler, M., Michlovitz, S., & Tierney, R. (2013). A descriptive study on wrist and hand sensori-motor impairment and function following distal radius fracture intervention. *Journal of Hand Therapy*, *26*, 204–215. https://doi.org/10.1016/j.jht.2013.03.004

Kehoe, R., & Rice, M. S. (2016). Reality, virtual reality, and imagery: Quality of movement in novice dart players. *British Journal of Occupational Therapy*, *79*, 244–251. https://doi.org/10.1177/0308022615616820

King, T. I. (1993). Hand strengthening with a computer for purposeful activity. *American Journal of Occupational Therapy*, *47*, 635–637. https://doi.org/10.5014/ajot.47.7.635

Lin, K., Wu, C. Y., Tickle-Degnen, L., & Coster, W. (1997). Enhancing occupational performance through occupationally embedded exercise: A meta-analytic review. *The Occupational Therapy Journal of Research*, *17*, 25–47. https://doi.org/10.1177/153944929701700102

Lin, K., Wu, C. Y., & Trombly, C. A. (1998). Effects of task goal on movement kinematics and line bisection performance in adults without disabilities. *American Journal of Occupational Therapy*, *52*, 179–187. https://doi.org/10.5014/ajot.52.3.179

Ma, H., Trombly, C. A., & Robinson-Podolski, C. (1999). The effect of context on skill acquisition and transfer. *American Journal of Occupational Therapy*, *53*, 138–144. https://doi.org/10.5014/ajot.53.2.138

Mehta, S., MacDermid, J. C., & Tremblay, M. (2011). The implications of chronic pain models for rehabilitation of distal radius fracture. *Hand Therapy*, *16*, 2–11. https://doi.org/10.1258/ht.2010.010022

Miller, L., & Nelson, D. L. (1987). Dual-purpose activity versus single-purpose activity in terms of duration on task, exertion level, and affect. *Occupational Therapy in Mental Health*, *7*, 55–67. https://doi.org/10.1300/j004v07n01_04

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., . . . Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, *4*, Article 1. https://doi.org/10.1186/2046-4053-4-1

Molineux, M. (2010). The nature of occupation. In M. Curtin, M. Molineux, & J. Webb (Eds.), *Occupational therapy and physical dysfunction: Enabling occupation* (p. 20). Elsevier.

Morton, G. G., Barnett, D. W., & Hale, L. S. (1992). A comparison of performance measures of an added-purpose task versus a single-purpose task for upper extremities. *American Journal of Occupational Therapy*, *46*, 128–133. https://doi.org/10.5014/ajot.46.2.128

Persson, D., & Erlandsson, L. (2010). Evaluating OVal-9, an instrument for detecting experiences of value in daily occupations. *Occupational Therapy in Mental Health*, *26*, 32–50. https://doi.org/10.1080/01642120903515284

Polatajko, H. J., Davis, J. A., Hobson, S. J., Landry, J. E., Mandich, A., Street, S. L., . . . Yee, S. (2004). Meeting the responsibility that comes with the privilege: Introducing a taxonomic code for understanding occupation. *Canadian Journal of Occupational Therapy*, *71*, 261–264. https://doi.org/10.1177/000841740507200307

Rice, M. S., Alaimo, A. J., & Cook, J. A. (1999). Movement dynamics and occupational embeddedness in a grasping and placing task. *Occupational Therapy International*, *6*, 298–310. https://doi.org/10.1002/oti.103

Rice, M. S., Davies, D. M., & Maitra, K. (2009). Immediate versus prolonged visual exposure and object relevancy in a reaching and placing task. *Al Ameen Journal of Medical Sciences*, *2*, 22–35.

Ross, L. M., & Nelson, D. L. (2000). Comparing materials-based occupation, imagery-based occupation, and rote movement through kinematic analysis of reach. *The Occupational Therapy Journal of Research*, *20*, 45–60. https://doi.org/10.1177/153944920002000103

Rice, M. S., & Renock, L. A. (2006). Personal preference and quality of reach in healthy adult women. *American Journal of Occupational Therapy*, *60*, 577–586. https://doi.org/10.5014/ajot.60.5.577

Sackaloo, K., Strouse, E., & Rice, M. S. (2015). Degree of preference and Its influence on motor control when reaching for most preferred, neutrally preferred, and least preferred candy. *OTJR: Occupation, Participation and Health*, *35*, 81–88. https://doi.org/10.1177/1539449214561763

Schmidt, R. A., & Wrisberg, C. A. (Eds.). (2008). *Motor learning and performance: A situation-based learning approach* (3rd ed.). Human Kinetics Press.

Squires, J. E., Valentine, J. C., & Grimshaw, J. M. (2013). Systematic reviews of complex interventions: Framing the review question. *Journal of Clinical Epidemiology*, *66*(11), 1215–1222. https://doi.org/10.1016/j.jclinepi.2013.05.013

Steinbeck, T. M. (1986). Purposeful activity and performance. *American Journal of Occupational Therapy*, *40*, 529–534. https://doi.org/10.5014/ajot.40.8.529

Taylor, S. A., Kedgley, A. E., Humphries, A., & Shaheen, A. F. (2018). Simulated activities of daily living do not replicate functional upper limb movement or reduce movement variability. *Journal of Biomechanics*, *76*, 119–128. https://doi.org/10.1016/j.jbiomech.2018.05.040

Wagner, M. R., Krauss, A., & Horowitz, B. (1995). Occupationally embedded exercise, rote exercise, and the presence of another person in an exercise context. *The Israeli Journal of Occupational Therapy*, *4*, 397–402.

Weinstock-Zlotnick, G., & Mehta, S. (2018). A systematic review of the benefits of occupation-based intervention for patients with upper extremity musculoskeletal disorders. *Journal of Hand Therapy*, *32*, 141–152. https://doi.org/10.1016/j.jht.2018.04.001

Wu, C. Y., Trombly, C. A., & Lin, K. (1994). The relationship between occupational form and occupational performance: A kinematic perspective. *American Journal of Occupational Therapy*, *48*, 679–687. https://doi.org/10.5014/ajot.48.8.679

Wu, C. Y., Trombly, C. A., Lin, K., & Tickle-Degnen, L. (1998). Effects of object affordances on reaching performance in persons with and without cerebrovascular accident. *American Journal of Occupational Therapy*, *52*, 447–456. https://doi.org/10.5014/ajot.52.6.447

Appendix B. Study II published article: A systematic review of daily activity and exercise recommendations and the efficacy and safety of early mobilisation following volar plating of distal radius fractures

Hand Therapy
2020, Vol. 25(4) 139–151

DOI: 10.1177/1758998320967032
journals.sagepub.com/home/hth
SAGE

A systematic review of how daily activities and exercises are recommended following volar plating of distal radius fractures and the efficacy and safety of early versus late mobilisation

Julie Collis[1], Nada Signal[2], Elizabeth Mayland[3] and Valerie Wright-St Clair[4]

Abstract

Introduction: Following surgical repair of distal radius fractures, mobilisation timeframes and interventions vary. Early mobilisation (<2 weeks postoperatively) usually includes range of motion exercises and may include recommendations to perform daily activities. The review investigated (i) how early mobilisation was recommended, particularly with respect to wrist use during daily activities and (ii) the efficacy and safety of early versus delayed mobilisation (< or ≥2 weeks).
Methods: The study protocol was registered on PROSPERO (CRD42019136490). Five databases were searched for studies that compared early and delayed mobilisation in adults with volar plating of distal radius fractures. The Downs and Black Quality Index and the Template for Intervention Description and Replication checklist were used for quality evaluation. Effect sizes were calculated for range of movement, function and pain at 6–8, 10–12 and 26 weeks. A descriptive analysis of outcomes and mobilisation regimes was conducted.
Results: Eight studies with a mean Quality Index score of 20 out of 28 (SD=5.6) were included. Performing daily activities was commonly recommended as part of early mobilisation. Commencing mobilisation prior to two weeks resulted in greater range of movement, function and less pain at up to eight weeks postoperatively than delaying mobilisation until two weeks or later.
Discussion: Performance of daily activities was used alongside exercise to promote recovery but without clearly specifying the type, duration or intensity of activities. In combination with exercise, early daily activity was safe and beneficial. Performing daily activities may have discrete advantages. Hand therapists are challenged to incorporate activity-approaches into early mobilisation regimes.

Keywords
Activities of daily living, distal radius fracture, early mobilisation, occupation, review articles

Date received: 30 May 2020; accepted: 24 September 2020

Introduction

Following surgical treatment of distal radius fracture it is common practice to commence mobilisation of the wrist within two weeks of surgery.[1] Delaying movement for longer than two weeks has been associated with greater wrist stiffness and poorer outcomes.[2] Wrist mobilisation following surgical distal radius fracture repair is predominantly facilitated by active range of motion (ROM) exercises, but may also be promoted through the performance of daily activities when a

[1]School of Clinical Sciences, Auckland University of Technology, Auckland, New Zealand
[2]Health & Rehabilitation Research Institute, Auckland University of Technology, Auckland, New Zealand
[3]School of Health and Society University of Wollongong, New South Wales, Australia
[4]School of Clinical Sciences and Centre for Active Ageing, Auckland University of Technology, Auckland, New Zealand

Corresponding author:
Julie M Collis, School of Clinical Sciences, Auckland University of Technology, 90 Akoranga Drive, Northcote, Auckland 0627, New Zealand.
Email: Julie.collis@aut.ac.nz

splint is removed.[3] Engaging in daily activities within the first two weeks of rehabilitation may be advantageous in promoting use of familiar movement patterns, building self-efficacy, augmenting movement volume, mitigation of pain, and facilitating engagement in therapy[4–7] and may be equally effective as exercise routines.[8] While therapeutic exercise for early mobilisation following surgical repair of distal radius fracture is widely practised,[8,9] the safety and benefit of including daily activities in the first two weeks of postoperative rehabilitation has not been established.

Hand therapists are increasingly being challenged to use activity and occupation-based interventions in clinical practice to facilitate more holistic, patient-focused therapy,[4,10] but evidence is lacking to support the safety of daily activities after surgical repair of distal radius fracture. Additionally, while activity in early mobilisation regimes is frequently alluded to in the literature, it is often poorly defined and may be overlooked as an independent therapeutic intervention.[7,11] As it is often not included in the description of postoperative regimes, but may be used in clinical practice, it is possible that early activity following surgical treatment of distal radius fractures has greater benefit than is currently understood. The lack of reporting hinders therapeutic use of evidence-based safe activity and may result in inconsistent advice on activity performance for patients in the early postoperative period. It may also lead to conservative approaches that delays performance of daily activities until two weeks or later, due to safety concerns.

The review therefore had two objectives: (i) to explore how mobilisation, in particular performance of daily activities without a splint, was recommended following volar plating of distal radius fractures in early mobilisation regimes; (ii) to evaluate the efficacy and safety of early versus delayed mobilisation. Efficacy was evaluated by determining whether there was greater wrist and forearm movement, better self-reported function and lower pain in early mobilised groups compared with delayed mobilisation. Safety was defined as adverse events occurring at equal or lower rates in early mobilisation regimes when compared with delayed mobilisation.

Methods

A systematic review was undertaken following the preferred reporting items for systematic reviews and meta-analysis (PRISMA) recommendations.[12] The study protocol was registered on PROSPERO (CRD42019136490). In March 2020, the primary author (JC) searched CINAHL Complete, MEDLINE and SPORTDiscus (via EBSCOhost), and OVID Emcare and AMED (via Ovid) to identify relevant studies. The full electronic search strategy for MEDLINE is in Supplementary File 1. Comparative studies that evaluated the outcomes of early and delayed mobilisation were included. Only fractures treated with volar plates were included because of the more complex nature of dorsal plate treatment.[1] Publication date was after the year 2000 to reflect the timeframe when volar plating became common practice. Case series were excluded due to large numbers of surgical studies providing minimal details on postoperative regimes and because they did not directly evaluate postoperative management. There is no accepted timeframe for delineating early and delayed mobilisation. It was defined in the review as occurring prior to or later than two weeks postoperatively. The timeframe was set to reflect clinical practice where mobilisation often commences at the first postoperative appointment. Mobilisation regimes were those that used ROM exercises and may or may not have included the performance of daily activities without a splint. Activity was defined as purposeful actions and sets of tasks performed by individuals on a day to day basis.[13,14] They denote purpose and meaning, and when grouped together constitute the broader occupations of work, play, leisure, daily living activities and social participation.[13] Full eligibility criteria are listed in Table 1. Search results from each database were exported to EndNote™ X8, citations combined and duplicates

Table 1. Inclusion and exclusion search criteria.

Inclusion criteria:	Exclusion criteria:
Adults aged ≥18 years	Systematic or narrative reviews, case series, position papers
Volar plating of a distal radial fracture	
Randomised controlled trial or comparative observational study	
Mobilisation within two weeks of surgery: treatment regimes that included exercises and may include performance of daily activities without a splint	
Compared with mobilisation delayed until two weeks or later: treatment regimes that included exercises and may include performance of daily activities without a splint	
Published after 2000	

removed. Titles and abstracts were reviewed to remove studies not meeting inclusion criteria. Full texts of remaining articles were screened for inclusion. Reference lists of systematic reviews and included studies were searched for missed studies.

Data extraction

The following data were extracted from the included studies by the primary author (JC) based on the criteria agreed between authors: author, date, study design, fracture type and participant characteristics. Intervention data extracted were exercise types, splint use and performance of daily activities (timeframes, types, intensity, therapeutic use). Further information on postoperative interventions was requested from authors of all studies, particularly to clarify instructions given about daily activities. Additional information was received from five authors[15–19] and there was no reply from three.[20–22] Activity and exercise data were tabulated and reported descriptively. Outcome data were ROM, function, pain, and adverse events. Outcomes were grouped into 6 to 8, 10 to 12 and 24 to 26 weeks to facilitate comparisons across studies. Outcome data were reported as group means and standard deviations. Effect sizes were calculated for the outcomes of wrist extension and flexion, pronation and supination. Disabilities of the Arm, Shoulder and Hand (DASH) or the Patient Rated Wrist Evaluation (PRWE) and pain, on the difference between groups, according to Hedges *g*, where 0.2, 0.5 and 0.8 indicates a small, medium and large effect respectively.[23] Estimation of standard deviations was conducted if not provided.[24]Meta-analyses could not be conducted because, although all studies compared early and delayed mobilisation, there were insufficient high-quality studies with equivalent purpose, design and outcomes at equivalent follow-up timeframes.

Assessment of methodological quality

Risk of bias was assessed at the study level using the validated Downs and Black Quality Index[25] by two authors (JC and NS). The index evaluates methodological study quality and is suitable for randomised and observational studies. The final score, out of 28 points, was assigned one of four grades, in line with previous reviews, to give an overall rating: 'excellent' for 26–28 points, 'good' for 20–25 points, 'fair' for 15–19 points and 'poor' for ≤14 points.[26] Where items were scored differently consensus was reached through discussion. A level of evidence was assigned to each study according to the Oxford Centre for Evidence-Based Medicine (CEBM) 2011 Levels of Evidence[27] by the first author (JC). The quality of postoperative intervention reporting was evaluated by the Template for Intervention Description and Replication (TIDieR) checklist.[28] The TIDieR was developed in 2014, as an extension to the CONSORT 2010[29] and SPIRIT 2013[30] statements[28] to evaluate and promote better reporting of interventions. For each item, the article was scored as not reported (0), partially reported (1) and adequately reported (2), according to the method described by Yamato et al.[31] A summary score ranging from 0 (poor reporting) to 24 (good reporting) was assigned.

Results

The study selection process is detailed in Figure 1. Following duplicate removal, 2179 articles were located across five databases. An additional article was found by searching reference lists. The titles and abstracts of 2180 articles were screened by a single author (JC). Twenty articles were identified for full-text review, of which eight were included in the final review.

Description of studies

Study design and participant characteristics are detailed in Table 2. A total of 519 participants were included across eight studies. The largest trial randomised 133 participants across three groups[16] and the smallest cohort had 23 participants.[15] There was a majority of females (72%), with a mean age range across all participants of 48 to 63 years. Two studies included only AO[32] type A fractures; in the remaining six studies 72% had AO types B or C. Across all 519 participants 52% had AO type B or C fractures. Of the eight included studies, five were level II Oxford CEBM levels of evidence[27] randomised controlled trials (RCTs)[16–19,22] with the remaining three being level four retrospective chart reviews.[15,20,21] The studies all compared early and delayed mobilisation (< or ≥2 weeks) but varied with respect to purpose. Four studies aimed to determine the optimal period of immobilisation.[16,19,21,22] The purpose of the remaining studies was to evaluate use of analgesia,[18] compare home and outpatient rehabilitation,[17] achievement of minimal clinically important differences for the DASH score[20] or compare numbers of hand therapy appointments.[15] In the early groups, mobilisation was commenced at an average of 4 days (range 1–8) and delayed until an average of 30 days (weeks two,[17,18,20,21] three,[16] five[22] or six[15,16,19]) in the immobilised groups (see Table 3).

Performance of daily activities in early mobilised groups

The activity interventions are detailed in Table 3. In all studies, daily activities were advocated, without a

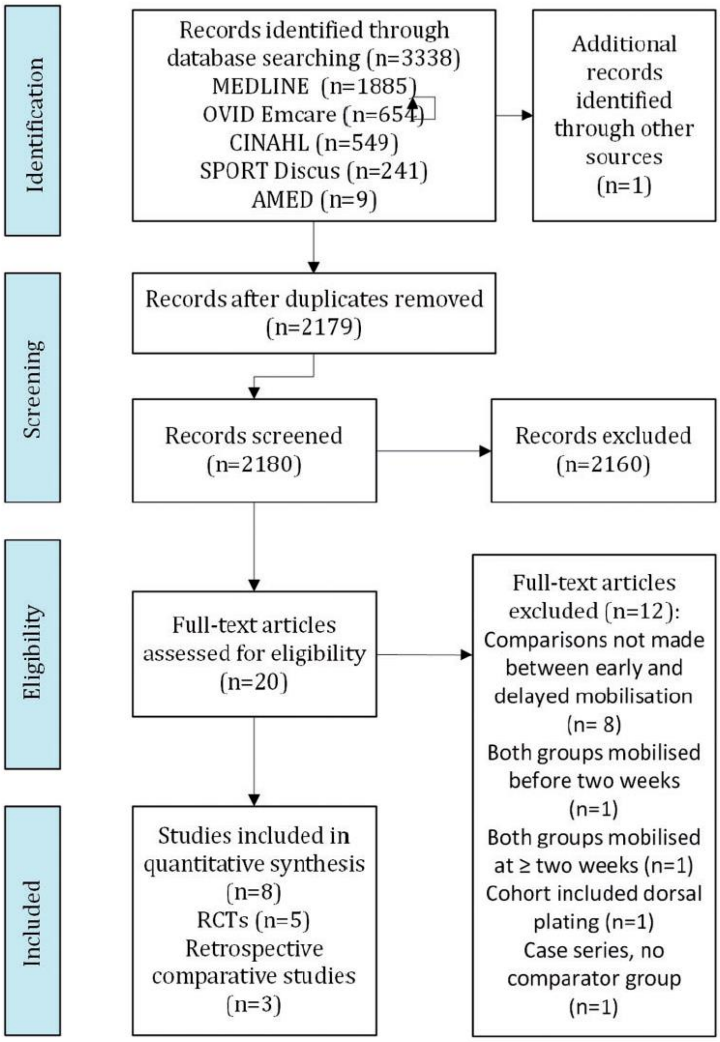


Figure 1. PRISMA flow diagram.

splint, from the time of mobilisation. Duprat et al.[21] did not describe daily activity performance but because a splint was not given it is assumed participants were free to use the wrist. Iitsuka et al.[20] also did not describe splint use or daily activities but the paper implied no splint was used. The types and intensity of activities lacked detail and were described in broad terms such as light activities, hygiene, eating, dressing, showering or lifting less than 2 kg. No study investigated activity-based interventions as an independent variable. Two studies reported an approach where activities were used for the purpose of exercising the wrist.[16,19] Of note, Watson et al.[16] took a collaborative approach, agreeing on activities that promoted wrist movement and those that were enjoyed where possible.

Outcomes

The results demonstrated that in groups where the performance of activities and ROM exercises were commenced prior to two weeks, there was generally greater wrist and forearm ROM and better function at up to eight weeks than when mobilisation was delayed until two weeks or later. Effect sizes are detailed in Table 2 and full outcomes in Supplementary File 2.

Table 2. Characteristics and main outcomes of the included studies in order of quality.

Author	Level of evidence[a] Study design Quality of evidence[2]	Study purpose	AO classification (type A, B or C)[c]	Characteristics	Outcomes	Effect sizes at 6–8 weeks, EM vs. DM	Effect sizes at 10–12 weeks, EM vs. DM	Effect sizes at 26 weeks, EM vs. DM
Watson	Level 2	Compared (a) 1 week,	A: 12%	Total $n = 133$	1 vs. 6 weeks:			
et al.[16]	RCT	(b) 3 weeks and	B: 67%	(a) $n = 46$	Wrist extension	Medium	NR	Small
	Quality of evidence:	(c) 6 weeks	C: 18%	Mean age 54.0 ± 15.6	Wrist flexion	Large	NR	None
	Excellent	immobilisation	Unknown: 3%	Female: 63%	Supination	Small	NR	None
				DHI: 41%	Pronation	Small	NR	None
				(b) $n = 41$	DASH	Medium	NR	None
				Mean age 51.1 ± 14.9	PRWE	Medium	NR	None
				Female: 75.6%	Pain: NRS-11	None	NR	Small
				DHI: 29%	1 vs. 3 weeks:			
				(c) $n = 46$	Wrist extension	None	NR	Medium
				Mean age: 52.0 ± 15.9	Wrist flexion	None	NR	Small
				Female: 54%	Supination	None	NR	Small
				DHI: 39%	Pronation	None	NR	Small
					DASH	None	NR	None
					PRWE	None	NR	Small
					Pain: NRS-11	None	NR	Small
Clementsen	Level 2	Compared (a) EM	A: 100%	Total $n = 119$	Wrist extension	Small	None	NR
et al.[17]		(2–3 days)		(a) $n = 57$	Wrist flexion	None	None	NR
	RCT	and fortnightly physio-		Mean age: 55 ± 12.4	Supination	Small	None	NR
		therapy with		Female: 93% DHI: 49%	Pronation	Small	None	NR
	Quality of	(b) 2 weeks		(b) $n = 62$	Quick	Small	None	NR
	evidence: Good	immobilisation and a single		Mean age: 55 ± 11.9	DASH	Small	None	NR
		physiotherapy visit		Female: 89%	PRWE	Small	None	NR
				DHI: 53%	Pain: VAS			
Andrade-Silva	Level 2	Compared (a) EM (imme-	A: 0%	Total $n = 39$	Wrist extension and			
et al.[18]		diate, no splint) with (b)	B: 1%	(a) $n = 19$	flexion arc	None	None	None
	RCT	immobilisation in a	C: 97%	Mean age: 51.2 ± 16.6	Supination and pronation			
		splint for 2 weeks		Female: 58% DHI: 47%	arc	Small	None	Small
	Quality of			(b) $n = 20$	Quick	None	Medium	Small
	evidence: Good			Mean age: 47.6 ± 15.1	DASH,	Small	Medium	
				Female: 55%	Pain: NRS-11			Small
				DHI: 60%				
Lozano-Calderón	Level 2	Compared (a) EM	A: 38%	Total $n = 60$	Wrist extension	NR	None	Small
et al.[19]		(<14 days) with	B: 13%	(a) $n = 30$	Wrist flexion	NR	None	None
	RCT	(b) 6 weeks	C: 48%	Mean age: 55	Supination	NR	Small	None
		immobilisation		Female: 63%,	Pronation	NR	None	None
	Quality of			(b) $n = 30$	Quick	NR	None	None
	evidence: Good			Mean age: 51	DASH,	NR	None	Small
				Female: 67%	Pain: NRS-11			
Quadlbauer	Level 2	Compared (a) EM (imme-	A: 3.5%	Total $n = 28$	Wrist extension	Large	Medium	Large
et al.[22]		diate) with (b) 5 weeks	B: 3.5%	(a) $n = 15$	Wrist flexion	Large	Medium	Large
	RCT			Mean age: 49.13 ± 15.41	Supination	Medium	None	Medium

(continued)

Table 2. Continued.

Author	Level of evidence[a] Study design Quality of evidence[2]	Study purpose	AO classification (type A, B or C)[c]	Characteristics	Outcomes	Effect sizes at 6–8 weeks, EM vs. DM	Effect sizes at 10–12 weeks, EM vs. DM	Effect sizes at 26 weeks, EM vs. DM
		immobilisation	C: 93%	Female: 63%	Pronation	Medium	None	None
	Quality of evidence: Fair			DHI: 53%	Quick	Large	Medium	Medium
				(b) $n = 13$	DASH	Large	Small	Medium
				Mean age: 58.77 ± 12.06	PRWE	Small	Small	Small
				Female: 67%	Pain: NRS-11			
				DHI: 46%				
Valdes[15]	Level 4	Compared (a) EM (at 1 week) with	Type A: 100%[d]	Total n = 23	Data for 1 vs. 6 weeks immobilisation:	(at start of hand therapy 1or 6 weeks)	(at discharge: mean 5 weeks for EM, 10 weeks for DM)	
				(a) $n = 14$				
	Retrospective chart review	(b) 6 weeks immobilisation		Mean age: 62.79 ± 12.10				
				Female: 78%	Wrist TAM			
				DHI: 28%	Forearm TAM	Small		
	Quality of evidence: Fair			(b) $n = 9$	ULFI:	Small	Small	
				Mean age: 55.22 ± 12.54	No. of therapy visits to reach 40° wrist extension and flexion	Small	Small	
				Female: 67%			Small	
				DHI: 67%			Large	
					No. of days to reach 40° wrist extension and flexion		Large	
Duprat et al.[21]	Level 4	Compared (a) EM (immediate, no splint) with (b) immobilisation in a splint for 2 weeks	A: 54%	Total $n = 72$	Wrist extension	NR	None	NR
			B: 1%		Wrist flexion	NR	Medium	NR
	Retrospective chart review		C: 45%	(a) $n = 36$	Supination	NR	Small	NR
				Mean age: 61 ± 17.4	Pronation	NR	None	NR
				Female: 69%,	Quick	NR	None	NR
	Quality of evidence: Fair				DASH	NR	None	NR
				(b) $n = 36$	PRWE	NR	Small	NR
				Mean age: 58 ± 14.7 Female: 80%	Pain: VAS			
Iitsuka et al.[20]	Level 4	Compared MCID for function for (a) EM (<day 3) with (b) immobilisation for 2 weeks	A: 20%	Total n = 45	Data for group where there was a MCID for DASH:			
			B: 9%	(a) $n = 27$				
	Retrospective chart review		C: 71%	Mean age: 57 ± 13				
				Female: 74% DHI: NRv	Wrist extension	Small	None	NR
					Wrist flexion	None	None	NR
	Quality of evidence:			(b) $n = 18$	Supination	Small	Small	NR
				Mean age: 49 ± 19	Pronation	None	Small	NR
				Female: 56%	Quick	Small	Medium	NR
				DHI: NR	DASH	NR	NR	NR
					Pain: VAS			

Values are mean ± SD or as otherwise indicated.
[a]Level of evidence according to the Oxford Centre for Evidence-Based Medicine (CEBM) 2011 Levels of Evidence.[27]
[b]Quality of evidence according to the Downs and Black Quality Index.[25]
[c]Type A: extra-articular; Type B: partial articular; Type C: complete articular.[32]
[d]AO classification was applied.
AROM: active range of movement; DASH: disabilities of the arm shoulder and hand; DHI: dominant hand injured; DM: delayed mobilisation EM: early mobilisation; MCID: minimal clinically important difference NR: not reported; NRS: numeric rating scale; PRWE: patient rated wrist evaluation; RCT: randomised controlled trial; ROM: range of movement; ULFI: upper limb functional index; VAS: visual analogue scale.

Table 3. Description of interventions for early mobilisation (EM) groups.

Author	EM: mean no. of days surgery to mobilisation	DM: mean no. of days surgery to mobilisation	Exercise intervention	Removable splint provided when mobilised	Daily activities performed without splint	Activity types	Intensity	Therapeutic use[a]
Watson et al.[16]	7	21 or 42	AROM wrist, thumb and finger exercises, 15 repetitions 1× per day	No	Yes	Negotiation of daily activities between patient and therapist, focus on enjoyed activities	ND	Daily activities collaboratively agreed between therapist and patient, linked where possible with movements similar to exercises
Clementsen et al.[17]	2–3	14	AROM 4×/day Passive stretching introduced after day 14	No	Yes	ADLs	Non-weight bearing until day 13, load-bearing as tolerated from day 14	No
Andrade-Silva et al.[18]	1	14	AROM wrist exercises	No	Yes	Light ADLs within pain limits	No impact activities or excessive effort in the first 14 days	No
Lozano-Calderón et al.[19]	8	49	Active and active-assisted wrist ROM exercises	Yes	Yes	Light ADLs	Lifting <2.5 kg	Encouraged to perform light ADLs for the purpose of 'exercising' the wrist
Quadlbauer et al.[22]	1	35	AROM wrist and finger exercises	Yes	Yes	Light ADLs	Light	No
Valdes[15]	7	42	AROM wrist and finger, PROM of digits	Yes	Yes	Light ADLs Guided by pain	<1kg	No
Duprat et al.[21]	1	14	Wrist AROM	No	Yes	Light ADLs	Light	No
Iitsuka et al.[20]	1–3	42	Wrist AROM	No[b]	Yes[b]	ND	ND	No

[a]Activities and occupations selected as interventions to meet specific therapeutic goals.[13]
[b]Use of a wrist splint was not reported but assumed from the content of the paper. Performance of daily activities without a splint was therefore inferred.
ADL: activities of daily living; AROM: active range of motion; DM: delayed mobilisation; EM: early mobilisation; ND: not described.

Studies comparing <2 weeks with two to three weeks immobilisation

Five studies[16–18,20,21] compared mobilisation that commenced prior to two weeks with mobilisation that was delayed until two to three weeks. Of these, three were of good or excellent quality.[16–18]

Range of movement. At the six- to eight-week follow-up, greater wrist movement was observed with small effect sizes for forearm or wrist range of movement in three studies, in favour of early mobilisation,[17,18,20] whereas no differences were observed in the study with the lowest risk of bias.[16] In two low-quality studies, small or medium effects were seen at 10 to 12 weeks for some ROM measures.[20,21] At 26 weeks, small and medium effects in favour of the early mobilised groups were observed in one good[18] and one excellent[16] quality study, for some ROM outcomes. In neither of these studies did the authors report these as statistically significant differences.

Function. Self-reported functional scores for the DASH were better in two studies in the early mobilised groups[17,20] with a small effect size at the six- to eight-week follow-up. At 10 to 12 weeks one study[20] reported a small effect size for the DASH and a medium effect at 26 weeks.

Pain. For pain outcomes, two studies[17,18] showed lower pain with small effect sizes, in the early mobilised groups at six weeks follow-up and in one study this was maintained at 10 to 12 and 26 weeks.[18]

Studies comparing <2 weeks with five- to six-weeks immobilisation

Four studies compared mobilisation that commenced prior to two weeks with five to six weeks immobilisation.[15,16,19,22] Larger effect sizes were seen in these studies than the previous comparison. Two of these were of good or excellent quality.[16,19]

Range of movement. In the studies that reported six- to eight-week follow-up there was greater extension,[16,22] flexion[16,22] and forearm rotation[16,22] with predominantly medium to large effects. At 10 to 12 weeks, small non-significant effects of early mobilisation were observed for supination in one study[19] and in another study,[22] medium effects were seen for wrist ROM.

Valdes[15] investigated the number of visits and days required to attain 40° wrist extension and flexion, demonstrating significantly fewer visits and days with a large effect size, for patients who were mobilised prior to two versus six weeks.

Function. Better function was reported in two studies at six- to eight-week outcomes[16,22] with medium and large effects. In one fair quality study,[22] a medium effect for function was observed at 10 to 12 weeks and this was maintained at 26-week follow-up.

Pain. Lower pain was reported in two studies at six- to eight-week outcomes[16,22] with small effects. In one of these studies,[22] lower pain was maintained at the 10 to 12 weeks and 26 weeks follow-up with small effects.

Adverse events. Adverse events are reported in full in Supplementary File 2. There were losses of fracture reduction reported in two studies at slightly higher rates in the early mobilised groups.[16,18] In those studies, the differences were not statistically different. No other study reported losses of fracture reduction. Other complications were tendon rupture, carpal tunnel syndrome, tendinitis, complex regional pain syndrome (CRPS), and infection with no statistically significant differences between groups reported in any study.

Quality assessment

The scores from the quality assessment are shown in Table 4. The mean score was 20/28 (range 10–27). One study was graded as excellent,[16] three as good,[17–19] three as fair[15,21,22] and one as poor quality.[20] CEBM levels of evidence are shown in Table 2. Randomisation occurred in all but the three retrospective studies.[15,20,21] Participants were unable to be blinded to interventions in any study. Assessors blinded to group allocation were used in five studies.[16–19,22] Calculations for sample size were conducted in four of the RCTs at a significance level of 0.05 and power of 80% based on detecting differences in pain,[18] function[16,17] and wrist ROM.[19] Of the eight studies, three failed to make adjustments for multiple analyses[18,20,22] and in three studies, confounding variables such as different surgeons or sites were not accounted for.[15,20,21]

Results from the TIDieR checklist can be found in Supplementary File 3. The mean score was 8.5/24 (range 3–17), indicating an overall poor level of intervention reporting. Only one study provided details on educational materials given to participants.[15] In only two studies were comprehensive data given on procedures, interventions, who provided them, what modifications were made and how intervention adherence was assessed.[15,16]

Table 4. Scoring of the studies according to the Downs and Black Quality Index.

Author	Reporting										External validity			Internal validity – bias							Internal validity – confounding						Power	Score/28	Grade
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
Watson et al.[16]	1	1	1	1	2	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	27	Excellent
Clementsen et al.[17]	1	1	1	0	2	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	25	Good
Andrade-Silva et al.[18]	1	1	1	0	2	1	0	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	23	Good
Lozano-Calderón et al.[19]	1	1	1	0	2	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	1	1	23	Good
Quadlbauer et al.[22]	1	1	1	0	2	1	0	1	0	1	0	0	1	0	1	1	1	0	0	1	1	1	1	1	1	0	0	18	Fair
Valdes[15]	1	1	1	1	2	1	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	16	Fair
Duprat et al.[21]	1	1	1	0	1	1	1	1	0	0	1	0	1	0	0	1	1	1	0	1	1	1	0	0	0	0	0	15	Fair
Iitsuka et al.[20]	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	11	Poor

The final score, out of 28 points, was assigned one of four grades, in line with previous reviews, to give an overall rating: 'excellent' for 26–28 points, 'good' for 20–25 points, 'fair' for 15–19 points and 'poor' for ≤14 points.

Discussion

The review focused on two objectives. Firstly, to determine how early mobilisation regimes following distal radius fracture surgery were reported, with a particular focus on elucidating the inclusion of daily activities as part of early rehabilitation. Secondly, the efficacy and safety of early mobilisation regimes that commenced prior to two weeks was evaluated in comparison with mobilisation delayed until two weeks or later. The term early mobilisation is widely used in the literature, generally referring to the use of ROM exercises.[1] Exercise regimes are relatively well-understood whereas the influence of daily activity performance on recovery has lacked clarity and attention. While it was not possible to determine the degree to which early activity influenced return of function and movement, the review points to the important contribution of daily activities in rehabilitation. This small body of moderate quality evidence, in studies comparing mobilisation prior to and after two weeks of volar plate fixation of distal radius fractures, indicates that performance of daily activities in tandem with exercises prior to two weeks postoperatively is firstly, a common but unstructured component of early mobilisation regimes, secondly, effective in achieving greater ROM, earlier return to function, and lower pain at up to eight weeks following surgery and, thirdly, generally safe as part of early rehabilitation regimes.

Recommendations on activity use are lacking in the literature and the safety of early fracture loading has been debated.[9,33,34] In general, the review confirms the safety of early activity. The parameters of early activity were not well-defined in the studies but commonly described as needing to be light, non-forceful, and within pain limits. Safety was shown by the lack of difference in adverse events between groups. While there were slightly higher rates of fracture position loss in two studies in early groups,[16,18] these were not attributed to early mobilisation by the authors. It does, however, indicate a focus of further study. Any early mobilisation regime must be considered with respect to fracture severity, stability of fixation and associated soft tissue injury, and be individualised accordingly. The review nonetheless supports the safety of incorporating performance of daily activities into early rehabilitation.

The review shows that activity was recommended as part of early mobilisation regimens but highlights a lack of specification on the parameters of daily activities. With respect to splint use, the studies advocated the performance of activities without a splint in early groups, in some cases, immediately after surgery. There are two bodies of work that support this premise. The first is biomechanical and cadaveric research that demonstrated sufficient strength of volar locking plates in withstanding the forces of daily activities during early rehabilitation, in both extra- and intra-articular fractures.[35–42] The second is observational and surgical studies where light daily activity was advocated early after surgery with a splint removed.[43–47] Collectively, these studies corroborate the findings of the review that early performance of daily activities, without a splint is safe and is accepted clinical practice in many centres.

With respect to timeframes, early mobilisation was commenced prior to an average of day 4 postoperatively. This is a pertinent finding as therapists may be reticent to recommend activities in the initial weeks due to concerns about loading healing bone.[4,5,9] Commencing daily activities early after surgery may have particular benefit for some patients such as those at risk of greater joint stiffness, prolonged pain or a pattern of disuse.[5] Enabling early activity performance may build self-efficacy and confidence, factors which have been associated with better outcomes following surgery for distal radius fracture.[48] Activities of increasing load, complexity and challenge can be gradually introduced, and as mastery of these activities is achieved confidence and self-belief is built.[49] The findings of the review challenges hand therapists to consider earlier initiation of activity performance than may be traditionally practised.[9]

Recommendations regarding activity types and intensity were for the most part poorly described. Activity types were limited to self-care, those that avoided weight-bearing or lifting greater than 2 kg. Some studies referred to non-impact activities but did not give examples. Observations from the first author's clinical practice suggest that patients often seek guidance as to what activities they are able to engage in. While it may be difficult to specify activities due to the complexity of movement during activity,[4,50,51] more specific examples may be helpful. It would be beneficial in future research to examine the types of activities that could be recommended at various phases of bone healing.

Therapeutic use of activity, where activities or occupations are self-selected, meaningful and purposeful,[49] was only described in one study.[16] In that study, valued and enjoyed activities were cooperatively selected, modified and performed as part of a home programme to promote movement and functional recovery.[16] The unique advantages of activity or occupation-based interventions may be underutilised in hand and wrist injury rehabilitation.[7] Purposeful activities have been shown to enhance motor performance[7] and observed to augment movement volume in healthy and musculoskeletal populations.[4,52] It is reasonable to consider that the greater ROM, function and lower pain in the early groups were in part due to the performance of daily activities. The review draws attention to the potential for using purposeful activities and occupations in more intentional ways to enhance recovery from wrist fracture surgery.

The review investigated the effects of early performance of daily activities and exercise regimes on ROM, functional outcomes, and pain. The review suggested that there was greater ROM,[15,16,22,33] earlier return to function,[16,22,33] and less pain,[16] at up to eight weeks, than in groups where activity performance and wrist exercises were delayed until two weeks or longer. The effects were greatest in the studies that compared early mobilisation with five to six, as opposed to two or three weeks, of immobilisation. This is unsurprising as it would be expected that longer immobilisation would result in greater joint stiffness. It highlights the importance of minimising the period of immobilisation, wherever possible.

The benefits of better short-term outcomes should not be underestimated. Achieving earlier return of movement and function is likely to have wide-reaching implications for individuals and society. Benefits may include improved mood, well-being, quality of life, higher rates of patient satisfaction, reduced loss of earnings, less need for support services, fewer hand therapy appointments and less time away from recreational pursuits.[1,5,6,15,33,45] These early outcomes are purported to be highly advantageous to people with injury but are not always given attention in outcomes research.

The moderate quality of the evidence must be considered when interpreting the findings of the review. Quality issues were statistical analyses that did not take multiple comparisons into account, lack of blinded assessors and non-reporting of losses to follow-up. The predominant methodological flaw of the review was that, with the exception of one study,[16] fidelity of interventions was poorly addressed. Intervention fidelity refers to the degree to which interventions are reported and implemented in the manner intended.[53,54] Using the TIDieR scale, failings across all aspects of reporting and monitoring were noted. On the whole, interventions were inadequately or only partially described with respect to providers, locations, methods of delivery and personalisation of the programmes. Adherence was monitored in only one study.[16] The lack of fidelity in the postoperative interventions makes it difficult to determine whether the effects seen were due to the interventions themselves or other factors not acknowledged by the authors.

Limitations of the review include the small number of studies of varying purpose, design and quality. Low level observational studies were included, due to their relevance to the review question but influence the strength of the findings. Only one author conducted the search which could have resulted in missed studies and potential bias in selection of studies. Only one author assigned the level of evidence and scored the TIDieR, which may have resulted in under or over-representing the quality of the studies. Standard deviations in one study had to be estimated in order to calculate effect sizes.[19] Directions for future research are suggested including biomechanical evaluation of movement during daily activities after wrist surgery and investigating the independent effect of activities differentially from exercise approaches. Future qualitative enquiry may illuminate patient perspectives on how activities influence recovery from wrist fracture.

Conclusions

The review found evidence that performance of light, non-forceful daily activities, without a splint in situ, was commonly recommended in the first two weeks following volar plating of distal radius fractures as part of early mobilisation regimes. Findings suggest that a range of light activities can be safely initiated within two weeks of surgery and incrementally increased during the first six weeks. The parameters of early daily activities were poorly specified in most studies and is an area that should be addressed in future research. Greater ROM, earlier return to function and lower pain might be expected at six to eight weeks after distal radius fracture fixation if mobilisation is commenced within two weeks of surgery, compared with prolonged wrist immobilisation. There are important psychological and social benefits to achieving earlier return to function and these factors should have greater focus in future research. The early mobilisation regimes in the review included performance of daily activities without a splint alongside exercise routines and points to the role of both approaches in promoting recovery of movement and function following volar plating of distal radius fractures. It challenges hand therapists to incorporate activity into early postoperative rehabilitation, and to conduct further research into the mechanisms and effects of activity and occupation-based interventions.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethical approval

Ethical approval was not required as the research was a review of existing literature only.

Guarantor

JC.

Contributorship

JC, NS, EM and VW conceived the study. JC conducted the review and wrote all manuscript drafts. NS co-conducted the quality scoring. All the authors were involved in reviewing drafts and approved the final article.

ORCID iDs

Julie Collis https://orcid.org/0000-0002-6560-6287
Nada Signal https://orcid.org/0000-0001-9595-0532
Elizabeth Mayland https://orcid.org/0000-0002-7887-1071
Valerie Wright-St Clair https://orcid.org/0000-0002-7505-3946

Supplemental material

Supplemental material for this article is available online.

References

1. Ikpeze TC, Smith HC, Lee DJ, et al. Distal radius fracture outcomes and rehabilitation. *Geriatr Orthop Surg Rehabi* 2016; 7: 202–205.
2. Dennison DG, Blanchard CL, Elhassan B, et al. Early versus late motion following volar plating of distal radius fractures. *Hand* 2020; 15: 125–130.
3. Michlovitz SL, Festa L, et al. Therapist's management of distal radius fractures. In: Skirven TM, Osterman AL and Fedorczyk J (eds) *Rehabilitation of the hand and upper extremity*. 6th ed. Maryland Heights, MI: Mosby, 2011. pp.949–962.
4. Colaianni D and Provident I. The benefits of and challenges to the use of occupation in hand therapy. *Occup Ther Health Care* 2010; 24: 130–146. 2010/04/01.
5. Mehta S, MacDermid JC and Tremblay M. The implications of chronic pain models for rehabilitation of distal radius fracture. *Hand Ther* 2011; 16: 2–11.
6. Guzelkucuk U, Duman I, Taskaynatan MA, et al. Comparison of therapeutic activities with therapeutic exercises in the rehabilitation of young adult patients with hand injuries. *J Hand Surg Am* 2007; 32: 1429–1435.
7. Collis JM, Signal N, Mayland E, et al. Influence of purposeful activities on upper extremity motor performance: a systematic review. *OTJR (Thorofare NJ)* 2020.
8. Quadlbauer S, Pezzei C, Jurkowitsch J, et al. Rehabilitation after distal radius fractures: is there a need for immobilization and physiotherapy? *Arch Orthop Trauma Surg* 2020; 140: 651–663.
9. Smith DW, Brou KE and Henry MH. Early active rehabilitation for operatively stabilized distal radius fractures. *J Hand Ther* 2004; 17: 43–49.
10. Weinstock-Zlotnick G and Mehta S. A systematic review of the benefits of occupation-based intervention for

patients with upper extremity musculoskeletal disorders. *J Hand Ther* 2019; 32: 141–152.

11. Michlovitz SL, Harris BA and Watkins MP. Therapy interventions for improving joint range of motion: a systematic review. *J Hand Ther* 2004; 17: 118–131.
12. Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015; 4: 1.
13. Amini DA, Kannenberg K, Bodison S, et al. Occupational therapy practice framework. *Am J Occup Ther* 2014. 68: S1–S48.
14. Polatajko HJ, Davis JA, Hobson SJ, et al. Meeting the responsibility that comes with the privilege: introducing a taxonomic code for understanding occupation. *Can J Occup Ther* 2004; 71: 261–264.
15. Valdes K. A retrospective pilot study comparing the number of therapy visits required to regain functional wrist and forearm range of motion following volar plating of a distal radius fracture. *J Hand Ther* 2009; 22: 312–397.
16. Watson N, Haines T, Tran P, et al. A comparison of the effect of one, three, or six weeks of immobilization on function and pain after open reduction and internal fixation of distal radial fractures in adults: a randomized controlled trial. *J Bone Joint Surg* 2018; 100: 1118–1125.
17. Clementsen SØ, Hammer O-L, Šaltytė Benth J, et al. Early mobilization and physiotherapy vs. late mobilization and home exercises after ORIF of distal radial fractures: a randomized controlled trial. *JB & JS Open Access* 2019; 4: e0012–e0012.
18. Andrade-Silva FB, Rocha JP, Carvalho A, et al. Influence of postoperative immobilization on pain control of patients with distal radius fracture treated with volar locked plating: a prospective, randomized clinical trial. *Injury* 2019; 50: 386–391.
19. Lozano-Calderón SA, Souer S, Mudgal C, et al. Wrist mobilization following volar plate fixation of fractures of the distal part of the radius. *J Bone Joint Surg* 2008; 90: 1297–1304.
20. Iitsuka T, Iwatsuki K, Ota H, et al. The optimal rehabilitation period for patients with distal radius fractures according to the MCID in DASH scores; a preliminary study. *Hand Surg Asian Pac* 2016; 21: 161–166.
21. Duprat A, Diaz JJH, Vernet P, et al. Volar locking plate fixation of distal radius fractures: splint versus immediate mobilization. *J Wrist Surg* 2018; 7: 237–242.
22. Quadlbauer S, Pezzei C, Jurkowitsch J, et al. Early rehabilitation of distal radius fractures stabilized by volar locking plate: a prospective randomized pilot study. *J Wrist Surg* 2017; 6: 102–112.
23. Cooper H, Hedges L and Valentine J. *The handbook of research synthesis and meta-analysis*. 3rd ed. New York: Russell Sage Foundation, 2019.
24. Wan X, Wang W, Liu J, et al. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Methodol* 2014; 14: 135.
25. Downs SH and Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 1998; 52: 377–384.
26. Chudyk AM, Jutai JW, Petrella RJ, et al. Systematic review of hip fracture rehabilitation practices in the elderly. *Arch Phys Med Rehabil* 2009; 90: 246–262.
27. Howick J, Chalmers I, Glasziou TG, et al. The oxford levels of evidence 2, www.cebm.net/index.aspx?o = 5653 (2011, accessed 24 March 2020).
28. Hoffmann TC, Glasziou PP, Boutron I, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *Br Med J* 2014; 348: g1687.
29. Moher D, Hopewell S, Schulz KF, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *BMJ* 2010; 340: c869.
30. Chan A-W, Tetzlaff JM, Altman DG, et al. SPIRIT 2013 statement: defining standard protocol items for clinical trials. *Ann Intern Med* 2013; 158: 200–207.
31. Yamato T, Maher C, Saragiotto B, et al. Rasch analysis suggested that items from the template for intervention description and replication (TIDieR) checklist can be summed to create a score. *J Clin Epidemiol* 2018; 101: 28–34.
32. Fernandez D. Distal radius fracture: the rationale of a classification. *Chirurgie de la Main* 2001; 20: 411–425.
33. Brehmer JL and Husband JB. Accelerated rehabilitation compared with a standard protocol after distal radial fractures treated with volar open reduction and internal fixation: a prospective, randomized, controlled study. *J Bone Joint Surg Am* 2014; 96: 1621–1630.
34. Salibian AA, Bruckman KC, Bekisz JM, et al. Management of unstable distal radius fractures: a survey of hand surgeons. *J Wrist Surg* 2019; 8: 335–343.
35. Koh S, Morris RP, Patterson RM, et al. Volar fixation for dorsally angulated extra-articular fractures of the distal radius: a biomechanical study. *J Hand Surg Am* 2006; 31: 771–779.
36. Mansuripur PK, Gil JA, Cassidy D, et al. Fixation strength in full and limited fixation of osteoporotic distal radius fractures. *Hand* 2018; 13: 461–465.
37. Kim S-J, Jo Y-H, Choi W-S, et al. Biomechanical properties of 3-dimensional printed volar locking distal radius plate: Comparison with conventional volar locking plate. *J Hand Surg Am* 2017; 42: 747.e741–747.e746.
38. Alluri R, Longacre M, Pannell W, et al. Volar, intramedullary, and percutaneous fixation of distal radius fractures. *J Wrist Surg* 2015; 4: 292–300.
39. Cooper EO, Segalman KA, Parks BG, et al. Biomechanical stability of a volar locking-screw plate versus fragment-specific fixation in a distal radius fracture model. *Am J Orthop* 2007; 32: E46–E49.
40. Dahl WJ, Nassab PF, Burgess KM, et al. Biomechanical properties of fixed-angle volar distal radius plates under dynamic loading. *J Hand Surg Am* 2012; 37: 1381–1387.

41. Levin SM, Nelson CO, Botts JD, et al. Biomechanical evaluation of volar locking plates for distal radius fractures. *Hand* 2008; 3: 55–60.
42. Osada D, Viegas SF, Shah MA, et al. Comparison of different distal radius dorsal and volar fracture fixation plates: a biomechanical study. *J Hand Surg Am* 2003; 28: 94–104.
43. Osada D, Kamei S, Masuzaki K, et al. Prospective study of distal radius fractures treated with a volar locking plate system. *J Hand Surg Am* 2008; 33: 691–700.
44. Gong HS, Cho HE, Kim J, et al. Surgical treatment of acute distal radioulnar joint instability associated with distal radius fractures. *J Hand Surg Eur* 2015; 40: 783–789.
45. Drobetz H, Koval L, Weninger P, et al. Volar locking distal radius plates show better short-term results than other treatment options: a prospective randomised controlled trial. *World J Orthop* 2016; 7: 687–694.
46. Waterbury K, Husband J, Callinan N, et al. Beyond the research: an accelerated rehabilitation protocol for patients with distal radius fracture treated with open reduction internal fixation using volar locking plate, a retrospective review and comparison of outcomes with a surgeon directed independent exercise program. *J Hand Ther* 2016; 29: 372–373.
47. Kwan K, Lau TW and Leung F. Operative treatment of distal radial fractures with locking plate system – a prospective study. *Int Orthop* 2011; 35: 389–394.
48. Björk M, Niklasson J, Westerdahl E, et al. Self-efficacy corresponds to wrist function after combined plating of distal radius fractures. *J Hand Ther* 2020; 33: 314–319.
49. Hinojosa J and Blount M-L. *The texture of life: Occupations and related activities*. 4th ed. Bethesda, MD: American Occupational Therapy Association, Inc., 2014.
50. Daud AZC, Judd J, Yau M, et al. Issue in applying occupation-based intervention in clinical practice: a Delphi study. *Procedia Soc Behav Sci* 2016; 222: 272–282.
51. Dy LB and Yancosek KE. Introducing purposeful activity kits in a hand rehabilitation practice: effects on clinical practice patterns and job satisfaction among occupational therapy practitioners. *Hand Ther* 2017; 22: 3–12.
52. Wilson L, Roden P, Taylor Y, et al. The effectiveness of origami on overall hand function after injury: a pilot controlled trial. *Br J Hand Ther* 2008; 13: 12–20.
53. Hildebrand MW, Host HH, Binder EF, et al. Measuring treatment fidelity in a rehabilitation intervention study. *Am J Phys Med Rehabil* 2012; 91
54. Murphy SL and Gutman SA. Intervention fidelity: a necessary aspect of intervention effectiveness studies. *Am J Occup Ther* 2012; 66: 387–388.

Appendix C. Study II database search for MEDLINE via EBSCOhost

Supplementary File 1: Database search for MEDLINE via EBSCOhost

Limiters: date of publication 2000 to current; English language

Search modes: Boolean/Phrase

Expanders: apply equivalent subjects; apply related words

1. volar
2. fracture
3. volar N5 plat* OR surgery OR surgical OR "ORIF" OR "open reduction internal fixation"
4. activit*
5. hand therapy
6. physiotherapy OR physical therapy
7. rehabilitation
8. mobilis* OR mobiliz*
9. immobilis* OR immobiliz*
10. motion
11. movement
12. splint* OR cast OR orthosis OR orthotic
13. 1 AND 2 AND 3
14. 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12
15. 13 AND 14

Appendix D. Study II outcomes of the included studies in order of quality

Author, date	Intervention groups	Range of Motion mean ± SD vs mean ± SD, Hedges g ± SE	Pain	Function and grip	Results – adverse events, radiology
Watson et al.	Immobilised for (a) one week (b) three weeks (c) six weeks	(a) vs. (c) in degrees, 6 and 26 weeks Extension: 45.7±14.5 vs. 37.8±13.9, g=0.55±0.22 54.4±13.4 vs. 58.3±8.7, g=0.34±0.22 Flexion: 52.3±15.9 vs. 39.8±15.2, g=0.80±0.22 61.0± 15.0 vs. 61.7±11.1, g=0.05±0.22 Supination: 65.9±15.6 vs. 59.7±17.2, g=0.37±0.21 72.0±12.6 vs. 70.5±11.3, g=0.12±0.22 Pronation: 74.2±14.4 vs. 70.2±15.6, g=0.26±0.21 78.3±10.2 vs. 78.1±9.3, g=0.02±0.22	(a) vs. (c) VAS-U at 6 and 26 weeks 14.7±13.3 vs. 22.3±19.3, g=0.46±0.22 11.4±18.3 vs. 12.2± 17.5, g=0.04±0.22	(a) vs. (c) at 6 and 26 weeks DASH: 29.6±18.3 vs. 44.7±23.9, g=0.70±0.29 12.9±19.6 vs. 14.4±17.7, g=0.08±0.25 PRWE: 31.5±19.9 vs. 46.3±22.1, g=0.70±0.22 18.2±23.8 vs. 21.6±20.6, g=0.15±0.22 Grip strength (kgs): 14.9±9.9 vs.12.0±9.1, g=0.30±0.21 22.7±12.4 vs. 24.5±16.8, g=0.12±0.22	Loss of fracture position: 4 in (a), 1 in (c). Two patients in (a) required further surgery. EPL rupture: 1 in (a) and 1 in (b) Nerve damage: 3 in (b) Carpal tunnel syndrome: 1 in (a) and (c)
		(a) vs. (b) in degrees, 6 and 26 weeks Extension: 45.7±14.5 vs. 45.7±14.3, g=0.00±0.22 54.4±13.4 vs. 60.1±11.8, g=0.45±0.23 Flexion:	(a) vs. (b) VAS-U at 6 and 26 weeks 14.7±13.3 vs. 12.8±15.4, g=0.13±0.22 11.4±18.3 vs. 4.9±9.7, g=0.43±0.23	(a) vs. (b) at 6 and 26 weeks DASH: 29.6±18.3 vs. 33.1± 17.5, g=0.19±0.29 12.9±19.6 vs. 10.4± 14.7, g=0.14±0.26 PRWE:	

Author, date	Intervention groups	Range of Motion mean ± SD vs mean ± SD, Hedges g ± SE	Pain	Function and grip	Results – adverse events, radiology
		52.3±15.9 vs. 50.3±11.4, g=0.14±0.22 61.0± 15.0 vs. 63.8±12.6, g=0.20±0.23 Supination: 65.9±15.6 vs. 66.5± 15.1, g=0.04±0.22 72.0±12.6 vs. 75.1± 10.6, g=0.26±0.23 Pronation: 74.2±14.4 vs. 76.2± 9.1, g=0.16±0.22 78.3±10.2 vs. 80.5± 10.7, g=0.21±0.23		31.5±19.9 vs. 29.0± 19.0, g=0.13±0.22 18.2±23.8 vs. 13.5± 14.8, g=0.23±0.23 Grip strength (kgs): 14.9±9.9 vs. 14.1± 9.2, g=0.08±0.22 22.7±12.4 vs. 22.6±11.5, g=0.01±0.23	
Clementsen et al.	(a) Early mobilisation (at 2-3 days) (b) Two weeks immobilisation	(a) vs. (b) in degrees, 6 and 12 weeks Extension: 46.9±18.3 vs.42.9±17.4, g=0.22±0.19 62.2±14.5 vs. 60.1 ± 14.3, g=0.14±0.19 Flexion: 38.2±16.0 vs. 37.7±15.6, g=0.03±0.18 51.4±14.8 vs. 51.0±11.1, g=0.03±0.19 Supination: 60.4±27.4 vs. 59.8±26.5, g=0.02±0.18 75.8±18.5 vs. 78.6±15.5, g=0.16±0.19 Pronation:	(a) vs. (b) VAS at 6 and 12 weeks 1.8±1.8 vs. 2.2±1.7, g=0.22± 1.1±1.6 vs. 1.0±1.2, g=0.06±	(a) vs. (b) at 6 and 12 weeks QuickDASH: 29.5±19.4 vs. 37.3±19.1, g=0.4±0.18 17.1±16.8 vs. 17.3±14.4, g=0.01±0.19 PRWE: 29.6±21.3 vs. 35.7 ±21.2, g=0.29±0.18 17.0±18.6 vs. 15.9±15.8, g=0.06±0.19	(a) plate removal x6. Repeat osteosynthesis x 2 (b) plate removal x4 Non-significant difference 10% incidence of CRPS with no significant difference between groups

Author, date	Intervention groups	Range of Motion mean ± SD vs mean ± SD, Hedges g ± SE	Pain	Function and grip	Results – adverse events, radiology
		79.3±13.4 vs. 74.2±15.2, g=0.35±0.19 83.6±10.3 vs. 81.9±12.3, g=0.15±0.19			
Andrade-Silva et al.	(a) Immediate mobilisation (b)Immobilisation	(a) vs. (b) at 6, 12 and 24 weeks in degrees for arcs of motion Extension/flexion arc: 69.0±19.4 vs. 67.1±36.5, g=0.06±0.33 87.1±26.3 vs. 92.4±34.6, g=0.17±0.33 114.1±32.5 vs. 108.9±29.4, g=0.16±0.33 Forearm rotation arc: 141.0±29.0 vs. 152.7±27.3, g=0.41±0.33 163.2±34.2 vs. 157.9±21.0, g=0.19±0.33 170.0±17.5 vs. 165.8±17.3, g=0.24±0.33	(a) vs. (b) at 6, 12 and 24 weeks 2.8±2.0 vs. 2.2±2.8, g=0.24±0.33 0.7±1.0 vs. 1.8±2.6, g=0.53±0.33 1.1±1.4 vs. 1.7±2.9, g=0.25±0.33	(a) vs. (b) at 6, 12 and 24 weeks: DASH 32.6±22.3 vs. 36.5±19.3, g=0.18±0.33 12.2±13.4 vs. 20.4± 16.6, g=0.53±0.33 10.4±11.8 vs. 14.5± 20.5, g=0.24±0.33	(a) One patient had loss of fracture reduction at 6 weeks and underwent plate revision No other complications reported
Lozano-Calderón et al.	(a) Early mobilisation (within two weeks of surgery) (b) Six weeks immobilisation	(a) vs. (b) in degrees, 3 and 6 months[i] Extension: 49±12.5 vs. 51±13.75, g=0.15±0.26 56±12.5 vs. 59±12.5, g=0.24±0.26 Flexion: 55±15 vs. 56±18.75, g=0.06±0.25 68±13.75 vs. 67±15.25, g=0.07±0.25 Supination: 80±11.25 vs. 83±7.5, g=0.31±0.26 88±3.75 vs. 88±6.25, g=0.0±0.25 Pronation:	2.4±2.5 vs. 2.4±2.5, g=0.0±0.25 1.5±0.75 vs. 1.9±1.5, g=0.33±0.25	(a) vs. (b) at 3 and 6 months[i] DASH: 19±18 vs. 17±16.75, g=0.11±0.26 8.5±5.75 vs. 8.1±16.75, g=0.03±0.25 Grip: 18.4± 8.98 vs. 19.9±7.58, g=0.18±0.26 23±10 vs. 24.9±13.05, g=0.16±0.26	One carpal tunnel release in (a). One case of tendinitis in (a) and three in group (b) One slight radiocarpal joint volar subluxation in group (a) and three in (b) No significant radiographic changes in either group.

Author, date	Intervention groups	Range of Motion mean ± SD vs mean ± SD, Hedges g ± SE	Pain	Function and grip	Results – adverse events, radiology
		88±5 vs. 88±4.25, g=0.0± 90±2.5 vs. 90±0, g=0.0±			
Quadlbauer et al.	(a) immediate mobilisation (b) five weeks immobilisation	(a) vs. (b) in degrees, 6 weeks, 12 weeks, 6 months Extension: 45.33±8.76 vs. 20.77±11.88, g=2.32±0.48 60.33 ±10.26 vs. 50.00±17.56, g=0.71±0.38 69.67± 9.72 vs. 58.85±15.96, g=0.81±0.38 Flexion: 44.00±11.37 vs. 23.46±8.51, g=1.96±0.45 59.33±11.48 vs. 50.39±12.16, g=0.74±0.38 72.33±11.32 vs. 58.85±12.27, g=1.11±0.40 Supination: 57.00±22.27 vs. 43.85±15.02, g=0.66±0.38 73.67±15.64 vs. 70.38±17.61, g=0.19±0.37 83.67±7.67 vs. 75.39±12.66, g=0.78±0.38 Pronation: 61.67±13.97 vs. 51.15±13.56, g=0.74±0.38 77.00±5.92 vs. 75.31±13.37, g=0.16±0.37 81.67±5.88 vs. 80.77±7.60, g=0.13±0.37	(a) vs. (b) at 6 weeks, 12 weeks, 6 months 1.54±1.18 vs. 2.24± 1.96, g=0.43±0.37 0.60±0.99 vs. 0.88± 0.95, g=0.28±0.37 0.13±0.52 vs. 0.25±0.47, g=0.23±0.37	(a) vs. (b) at 6 weeks, 12 weeks, 6 months Quick DASH: 31.29±17.89 vs. 54.02±10.46, g=1.48±0.42 11.28±11.49 vs. 19.11±14.53, g=0.59±0.38 4.88± 6.76 vs. 11.46±11.70, g=0.68±0.38 PRWE: 36.13±12.87 vs. 49.35±14.60, g=0.94±0.39 11.57± 9.19 vs. 16.38± 14.95, g=0.38±0.37 4.22±5.26 vs. 10.23±9.93, g=0.75±0.38 Grip (kgs): 14.46±9.18 vs. 4.56±3.92, g=1.33±0.41 22.73±7.58 vs. 16.29±9.73, g=0.72±0.38 26.96±7.09 vs. 20.98±10.84, g=0.64±0.38	(a) one EPL rupture, one case of CRPS (b) no complications but two patients excluded due to CRPS and onset of multiple sclerosis No loss of reduction in either group requiring secondary intervention, no other significant radiological differences
Valdes	(a) early mobilisation (at one week)	(a) vs.(b) at initiation of hand therapy (one or six weeks) and at discharge	Not reported	(a) vs. (b) at initiation and of hand therapy (one or six weeks) and at 6 months	Two charts excluded from the review

Author, date	Intervention groups	Range of Motion mean ± SD vs mean ± SD, Hedges g ± SE	Pain	Function and grip	Results – adverse events, radiology
	(b) six weeks immobilisation	Wrist TAM[ii]: 40.36±35.7 vs. 55±32.66, g=0.4±0.42 92.07±40.25 vs. 102.66±21.27, g=0.30±0.41 Forearm TAM[ii]: 109.37±12.15 vs. 114±12.91, g=0.36±0.42 140.64±13.67 vs. 140.64±13.67, g=0.05±0.41 Number of days to attain 40° wrist extension and flexion: 34.79±10.90 vs. 71.89±18.33, g=2.52±0.55 No. of therapy visits to attain 40° wrist extension and flexion: 6.57±2.10 vs. 17±5.22, g=2.78±0.58		ULFI[ii]: 43.73±20.4 vs. 62.00±24.49, g=0.79±0.43 5.56±6.32 vs. 13.33±1.66, g=1.47±0.47 Grip[ii]: 19.07±18 vs. 23.33±23.52, g=0.20±0.41 35.29±11.76 vs. 34.78±12.48, g=0.04±0.41	based on one infection and one non-union. Radiological outcomes not reported No losses of reduction reported
Duprat et al.	(a) Immediate postoperative mobilisation (b) 2 weeks postoperative immobilisation	(a) vs. (b) as a percentage of the contralateral wrist at 12 weeks Extension: 83.40±16.76 vs. 83.13±16.02, g=0.02±0.23 Flexion: 85.50±14.79 vs. 74.83±21.59, g=0.57±0.24 Supination: 92.06±9.40 vs. 88.11±13.99, g=0.32±0.23 Pronation: 92.96±10.39 vs. 92.08±12.20, g=0.08±0.23	(a) vs. (b) VAS at 12 weeks 1.28±1.91 vs. 1.72±2.26, g=0.21±0.23	(a) vs. (b) at 12 weeks Grip reported as a percentage of the contralateral wrist Quick DASH: 19.57±16.44 vs. 21.78±21.31, g=0.11±0.23 PRWE: 20.56±14.05 vs 22.97±20.99, g=0.13±0.23 Grip: 66.34±19.34 vs. 62.96±28.77, g=0.14±0.23	No complications or surgical revision were reported for either group
Iisuka et al.	(a) early mobilisation (≤	(a) vs. (b) in degrees at 8 and 12 weeks (only data for group where	NR	(a) vs. (b) at 8 and 12 weeks	NR

Author, date	Intervention groups	Range of Motion mean ± SD vs mean ± SD, Hedges g ± SE	Pain	Function and grip	Results – adverse events, radiology
	day 3) (b) 2 weeks immobilisation	there was a minimal clinically important difference present is given here) Extension: 87.6 ± 6.4 vs. 84.0 ± 11.4, g=0.38±0.40 90.4 ± 11.0 vs. 90.6 ± 11.1, g=0.02±0.34 Flexion: 77.1 ± 13.2 vs. 78.9 ± 12.4, g=0.14±0.39 82.0 ± 11.0 vs. 82.9 ± 10.4, g=0.08±0.34 Supination: 89.2 ± 11.6 vs. 85.5 ± 8.7, g=0.35±0.40 92.7 ± 8.3 vs. 91.0 ± 5.9, g=0.23±0.34 Pronation: 94.3 ± 15.0 vs. 95.1 ± 8.5, g=0.06±0.39 96.4 ± 10.1 vs. 93.6 ± 9.3, g=0.28±0.34		DASH: 50.8 ± 10.6 vs. 57.9 ± 18.3, g=0.46±0.40 46.3 ± 12.0 vs. 54.7 ± 18.4, g=0.54±0.35 Grip: 54.4 ± 21.3 vs. 61.2 ± 27.9, g=0.26±0.40 70.7 ± 9.6 vs. 72.0 ± 17.1, g=0.09±0.34	

[i] Only means and range were provided. In order to calculate the effect size, SD was estimated based on the method described by Wan et al. (2014)
[ii] SD was calculated from graphs in the study

NOTE. Values are mean ± SD, Hedges g ± SE
Abbreviations: CRPS: complex regional pain syndrome; DASH: disabilities of the arm shoulder and hand; EPL: extensor pollicis longus; NR: not reported; PRWE: patient rated wrist evaluation; ROM: range of movement; SD: standard deviation; SE: standard error; TAM: total active movement; ULFI: upper limb functional index; VAS: visual analogue scale; VAS-U: visual analogue scale – usual

Appendix E. Study II TIDieR scoring

TIDieR
Template for Intervention Description and Replication

The TIDieR (Template for Intervention Description and Replication) Checklist*:

Information to include when describing an intervention and the location of the information

	Item	Andrade-Silva, Rocha, Carvalho, Kojima, and Silva (2018)	Clementsen, Hammer, Šaltytė Benth, Jakobsen, and Randsborg (2019)	Duprat et al. (2018)	Iitsuka, Iwatsuki, Ota, and Hirata (2016)	Lozano-Calderón, Souer, Mudgal, Jupiter, and Ring (2008)	Quadlbauer et al. (2017)	Valdes (2009)	Watson, Haines, Tran, and Keating (2018)
1.	**BRIEF NAME** Provide the name or a phrase that describes the intervention.	2	2	2	1	2	2	2	2
2.	**WHY** Describe any rationale, theory, or goal of the elements essential to the intervention.	1	1	1	1	1	1	2	1
3.	**WHAT** Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).	0	0	0	0	0	0	2	1
4.	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.	1	1	0	1	1	1	2	2
	WHO PROVIDED								

5.	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	1	1	0	0	1	1	2	1
	HOW								
6.	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	1	1	0	0	0	1	2	1
	WHERE								
7.	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	1	0	0	0	0	1	1	1
	WHEN and HOW MUCH								
8.	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.	0	1	0	0	0	1	1	2
	TAILORING								
9.	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.	0	0	0	0	0	0	1	2
	MODIFICATIONS								
10.‡	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	0	0	0	0	0	1	0	1
	HOW WELL								
11.	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	0	1	0	0	0	0	0	2

12.[‡]	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	0 7	1 9	0 3	0 3	0 5	0 9	0 15	1 17

For each item the article was scored as not reported (0), partially reported (1), and adequately reported (2) according to the method described by Yamato, Maher, Saragiotto, Catley, and Moseley (2018). A summary score ranging from 0 (poor reporting) to 24 (good reporting) was created.

Appendix F. Study III AUTEC approval letter 31 July 2019

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

31 July 2019

Valerie Wright-St Clair
Faculty of Health and Environmental Sciences

Dear Valerie

Re Ethics Application: **19/224 Patient perspectives on recovery of wrist motion after surgery for distal radius fracture**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 31 July 2022.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/research/researchethics.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/research/researchethics.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/research/researchethics.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation then you are responsible for obtaining it. You are reminded that it is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

For any enquiries, please contact ethics@aut.ac.nz

Yours sincerely,

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: juliecollis@gmail.com; nada.signal@aut.ac.nz

Appendix G. Study III Counties Manukau Health localities approval

COUNTIES MANUKAU HEALTH

Research & Evaluation Office
Level 1, Ko Awatea, Middlemore Hospital
100 Hospital Road, Otahuhu; Private Bag 93311, Auckland – 1640
cmdhb.org.nz – koawatea.co.nz

21 August 2019

For the attention of: Julie Collis

Thank you for the information you supplied to the CM Health Research Office regarding the following research proposal:

Research Registration Number: 1048

Ethics Reference Number: 19/224

Research Project Title: The influence of participation in meaningful occupations on wrist motion after surgical treatment of distal radial fracture

I am pleased to inform you that the CM Health Research Office has received all the required service lead approvals and the Chief Medical Officer's final sign-off for this research project, with you named as the CM Health Lead Investigator.

This CM Health locality approval is valid until 31 December 2020, as specified in your registration.

All external reporting requirements must be adhered to. Please note that failure to submit amendments and Annual Progress reports may result in the withdrawal of Ethical and CM Health organisational approval.

FINAL REPORT: It is a requirement of the CM Health Research Policy that all research and audit projects conducted within CM Health should have a written final study report submitted no later than 3 months following completion of the study. This report is to be uploaded to your study file on the Registry and is viewable by CMDHB staff. Contact us for the report template or download it from the Registry.

Yours sincerely

A Bennett.

Angela Bennett
Research Coordinator
Counties Manukau Health
Under delegated authority from CM Health Research Committee and the Chief Medical Officer

Appendix H. Study III researcher safety protocol

AUCKLAND UNIVERSITY OF TECHNOLOGY ETHICS COMMITTEE (AUTEC)

Researcher Safety Protocol

Project title and brief description:

Patient perspectives on recovery of wrist motion after surgery for distal radius fracture

A Qualitative study investigating patient's experiences and perception of how exercises and everyday activities contribute to recovery of wrist movement after surgery for distal radial fracture

The study involves a 60-minute consultation with the participant, completion of a daily exercise and activity log and a 60-minute semi-structured interview. The initial consultation and the interview will take place in the home of the participant.

Applicant

Professor Valerie Wright-St Clair

Primary Researcher

Julie Collis (JC)

Where is the research being undertaken?

The initial consultation and semi-structured interviews will be conducted in the homes of the participants

The homes will be anywhere within the region of Counties Manukau Health (CMH). The researcher will travel by private car. The researcher is familiar with using google maps for locating the correct address. Prior to the visit the primary researcher JC will speak with the participant to clarify address and any specifics regarding the address.

Prior to visiting JC will speak with the participant to obtain any particular instructions and where it is best to park

Who will be collecting the data and interacting with participants?

There will not be anyone accompanying the researcher

How familiar is the researcher with the social or cultural context of the research ?

The primary researcher has been working for Counties Manukau for 19 years and is familiar with interacting with a wide range of ages, genders and ethnicities. JC is very familiar with the nature of the injury that will be the focus of this investigation i.e. patients who have undergone surgery for distal radius fracture.

The primary researcher has taken part in Maori and Pacific Cultural Competency training.

JC will be consulting with CMH Maori research advisor prior to recruitment to discuss local protocols with respect to home visiting

Localities approval will be gained from CMH prior to the commencement of the research.

How safe are the activities in which the researcher is taking part?

The research activities do not involve risk or hazards.

What level of access to support is available?

JC will be attending two courses run through Counties Manukau Health

- Safe home-visiting course
- Online training module on Dog Do's and Don'ts

The researcher will have a mobile phone at hand at all times during the home visit. The researcher can use standard emergency contacts (111) if any emergency arises

What emergency plans are in place? Who can help?

These guidelines have been taken from the AUT PCR document 'Keeping safe in the community – May 2019' and Counties Manukau Health Community/Home-based Visiting Policy

Prior to the visit:

- When arranging the visit with the participant JC will check if there are any safety concerns. If there are dogs on the property it may be more appropriate to conduct the interview elsewhere
- Check with participant who else will be at home. Chat with the participant to establish early rapport.
- Clinical notes will be checked to ensure there are no alerts on the client/patient record (eg known infectious disease, violence/aggression, aggressive dogs etc).
- On the day JC will text or call the participant to confirm that they are still available and expecting the researcher
- I will inform two other people; Professor Valerie Wright-St Clair and a personal contact (husband, close friend) of the address to be visited and the expected timeframe of the visit. Location sharing will be activated via google maps with both contacts until the researcher notifies the two contacts that the researcher has left the address
- JC will ensure mobile phone is fully charged

On arrival and during visit

- Park facing the direction I wish to leave. Don't park up a driveway where you can be blocked in.
- Keep your keys on you
- Keep your mobile phone turned on (e.g. on silent)
- Be vigilant regarding the environment both outside and within the home.
- Look for evidence of dogs, drug use, isolation, no cell phone coverage, poor access to house/car, gang addresses, etc.
- If dogs or other dangerous animals are present, call participant from outside the property and ask that they be tied up or locked away before you enter. If that is not possible, leave and reschedule the visit.
- If participant or any person present is under the influence of drugs or alcohol, leave the premises and reschedule the visit.
- If you hear raised voices or observe violence, leave the premises and reschedule visit
- If concern or sense of unease is felt during the visit, JC will thank the participant and leave
- If necessary, de-escalation/calm strategies will be used
- In case of an emergency standard practice of calling 111 will be followed

Following visit

- Once safely in my car JC will notify contact people
- If my safety buddy has not heard from me as expected, then they will follow the following procedure
    - Call you to check I am ok
    - Call any other contact numbers for me
    - Call the home of the person I was visiting
    - Call my emergency contact, family member or next of kin
    - If they cannot locate me by any of the above means they will contact the police
-

- If concerns have been noted during the visit this will be discussed with supervisor/s and plans/decisions made regarding any further visits if still needed e.g. alternative venue, taking a support person

Don't forget to update your safety protocol regularly:

Date for next review

Appendix I: Study III participant information sheet

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Participant Information Sheet

Date Information Sheet Produced: 25th April 2019

Project Title: Patient perspectives on recovery of wrist movement after surgery for distal radius fracture (broken wrist)

An Invitation

Tēnā koe. Ko toku ingoa Julie Collis. I am inviting you to take part in a study about getting wrist movement back after your broken wrist.

Taking part in this study will involve three parts: i) an appointment to measure your wrist and fill in some questionnaires, ii) filling out a daily exercise and activity log, iii) a 60-90-minute interview with the researcher (Julie Collis) - see 'What will happen in this research?' for more information.

I am an Occupational Therapist and a New Zealand registered Hand Therapist with more than twenty years of experience. I work at the Manukau Super Clinic Hand Therapy Clinic and teach hand therapy at the Auckland University of Technology. At the moment I am doing a PhD (Doctor of Philosophy) researching about people who have had surgery for a broken wrist.

What is the purpose of this research?

The aim of this study is to learn about recovery of movement after a broken wrist. I want to find out about the exercises and activities you do in the first six weeks after your surgery. I want to learn how easy or hard it is for you to move your wrist, and what does and doesn't help. I want to hear about your experiences.

I am doing this research so that hand therapists can understand the best ways to help people after surgery. Hand therapists use different treatments like exercises, stretches, heat, massage, splints, strengthening and activities. I want to find out what you think helps your recovery. I especially want to find out about exercises and everyday activities.

The type of research in this project is called 'Qualitative research'. It is about talking to our patients and learning from them. This research will help hand therapists learn about ways to help our patients recover as quickly as possible after an operation.

How was I identified and why am I being invited to participate in this research?

You are being asked to participate because you had surgery for your broken wrist in the past two weeks. I am asking people over the age of 45, who have started their rehabilitation (having a splint and starting exercises) by two weeks after their surgery. I am not asking people who have had other injuries to their hands or wrists at the same time or people who have had a stroke or other neurological (nerve) condition (e.g. Parkinson's, Multiple Sclerosis)

How do I agree to participate in this research?

Taking part in this research is your choice. Your treatment will be the same if you are in the study or not. You can leave the study at any time. If you choose to leave the study, you can have any information that belongs to you removed or allow it to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

If you agree to take part, you will need to:

1. Attend a **60-minute appointment** at your home or the hand therapy clinic, at 2-3 weeks after your operation. I will ask you to sign a consent form to say you understand what is involved in the research. You will be asked to fill out some forms about yourself (age, gender, ethnicity, how you injured your wrist) and two questionnaires about using your hand. I will take some measurements of your wrist movement and explain about the activity log
2. Fill out a **daily exercise and activity log** each day for 3 to 4 weeks on your phone, computer or manually. The log has simple boxes which you can complete with either hand, or someone else can do it for you. This will take about 3-5 minutes each day You will start filling out this log from week 2 or 3 after your surgery and finish at six weeks after your surgery. You will be asked what exercises and activities you did that day, what your pain was like, how stiff your wrist felt, and whether you felt afraid or not about moving your hand and wrist. No one except the researchers will see this information.
3. Take part in a **60-90-minute interview** at six to eight weeks after your surgery at your home, or your hand therapy clinic. I will be talking to you about your recovery. The types of questions will be; What advice did you get about everyday activities? Tell me about the types of exercises and activities that you found helpful? Were there things that stopped you from doing exercises or activities. The interview will be audio recorded and transcribed (written out word for word). I will study the information from all the people in the study. I will look at what everyone says and come up with some common ideas and thoughts.

After I have completed the interviews and looked at the daily logs, I will be writing up the results. The findings of this research may be used for academic publications and presentations (e.g. at a conference).

What are the discomforts and risks?

This research should not be uncomfortable or risky for you. You won't be asked to do anything different from what your surgeon or hand therapist tells you. You will do your normal therapy the way you have been advised. During the interview you don't have to answer a question if you don't wish to and you can say as much or as little about your experiences as you would like. You may have whanau (family), a friend or cultural advocate present during the interview.

How will these discomforts and risks be alleviated?

I will ring you each week to see how you're going with the daily log and encourage you to keep going. You will be able to ring me if you have any questions. During the interview I will remind you that you don't have to talk about anything you don't wish to.

What are the benefits?

This study will help people who have a similar injury in the future. Hand therapists will be able to learn about the best ways to help our patients.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of the study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

All information that is collected will be kept private and confidential. Your daily log, interview recording, and transcript will be kept in a password protected computer. This research is completely separate from your hand therapy and I won't be talking to your therapist or surgeon and they won't be talking to me about the information you give. They won't know what you fill out in the forms or say in the interview. The only people who will have access to your information are the researchers involved in this project – Julie Collis and my PhD supervisors Professor Valerie Wright St-Clair, Dr Nada Signal and Dr Elizabeth Mayland. All data collected will be stored electronically and will be password protected. This data will be held for 10 years and then destroyed.

The findings will be written up in my PhD thesis and may be published in a conference paper or journal article. None of these publications will contain your name or have any other way of identifying you. These documents may use brief quotes or statements from your interview but will be anonymous (no name attached).

What are the costs of participating in this research?

No financial costs. The total cost in time will be four to five hours. This will be spread over 4-6 weeks.

Costs in time

1. 60 minutes appointment, at 2-3 weeks after your operation
2. Filling out daily log: 3-5 minutes each day for about 3 weeks
3. Doing a 60-90 minute interview, at 6-8 weeks after your operation

The 60-minute appointment and the 60-90 minute interview can be at your home or the hand therapy clinic. The appointments can happen when you have other appointments at Manukau Super Clinic or your hand therapy clinic.

I will arrange a location that is suitable for you.

A gift voucher of $40 will be given to all participants.

What opportunity do I have to consider this invitation?

Once I have talked to you on the phone you will have 2-5 days to consider if you wish to take part. This is not very long but is because I want to start the daily log from three weeks after your surgery. If you start the research and decide you don't want to continue you can leave at any time.

Will I receive feedback on the results of this research?

If you wish, I will send you a summary of the study results at the end of the project. I can provide you with a copy of your daily log or interview transcript if you would like me to. If there is a journal article published as a result of this research a copy will be made available to you.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Professor Valerie Wright St-Clair (valerie.wright-stclair@aut.ac.nz, +64 9 921 9999 ext 7736).

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details: Julie Collis, Julie.collis@aut.ac.nz, 021510083

Project Supervisor Contact Details: Dr Valerie Wright St-Clair, valerie.wright-stclair@aut.ac.nz, +64 9 921 9999 ext 7736

Approved by the Auckland University of Technology Ethics Committee on 30/07/2019; AUTEC Reference number 19/224

Appendix J: Study III consent form

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Consent Form

Project title:	**Patient perspectives on recovery of wrist motion after surgery for distal radius fracture**
Project Supervisor:	**Professor Valerie Wright St-Clair, Dr Nada Signal, Dr Elizabeth Mayland**
Researcher:	**Julie Collis**

○ I have read and understood the information provided about this research project in the Information Sheet dated 25th April 2019.

○ I have had an opportunity to ask questions and to have them answered

○ I agree to fill in a daily log for two to three weeks

○ I agree to take part in a 60 to 90-minute interview

○ I understand that notes may be taken during the interviews and that they will also be audio-taped

○ I understand that the interview will be transcribed (written down in full) after the interview

○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.

○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible

○ I agree to the researcher accessing my hospital discharge report, clinic notes, x-ray or bone scan, operation note, hand therapy or surgeon appointment times, relevant to this injury, from my hospital electronic records

○ I agree to take part in this research.

○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: ....

Participant's name: ....

Date : ....

Participant's Contact Details:

Mobile phone : ....

Home phone : ....

Email : ....

Address : ....

Date:

Approved by the Auckland University of Technology Ethics Committee on 30/07/2019; AUTEC Reference number 19/224

Note: The Participant should retain a copy of this form

Appendix K: Study III activity and exercise log

Activity and exercise log

* Required

1. Enter today's date, i tenei ra *

Format: M/d/yyyy

2. Were you able to do some wrist exercises/hei mahi today, with your wrist splint off? *

- No, none
- Yes, one or two times
- Yes, quite a few times

3. How difficult was it to do your exercises/hei mahi today? *

- Not at all difficult
- Moderately difficult
- Extremely difficult

4. How much pain/mamae did you have on average today? *

0	1	2	3	4	5	6	7	8	9	10

No pain/mamae — Worst possible pain/mamae

5. How stiff did your wrist feel today? *

0	1	2	3	4	5	6	7	8	9	10

Not at all stiff — Extremely stiff

6. Select any personal care activities you did today, where you did at least some of the activity with your wrist splint off

- ☐ Eating and drinking
- ☐ Getting dressed/undressed
- ☐ Showering/bathing
- ☐ Grooming; hair, teeth, shaving, makeup, nails
- ☐ Driving
- ☐ Using the bus
- ☐ Taking medications
- ☐ Other

7. Select any home activities/mahi whare you did today, where you did at least some of the activity with your wrist splint off

- ☐ Preparing breakfast, lunch or dinner
- ☐ Making a hot drink (tea/coffee/other)
- ☐ Shopping/putting shopping away
- ☐ Doing dishes, filling/emptying dishwasher
- ☐ Laundry/washing e.g. hanging out laundry, putting laundry away
- ☐ Cleaning
- ☐ Keeping outdoors tidy
- ☐ Pet care
- ☐ Other

8. Select any work/mahi activities you did today, where you did at least some of the activity with your wrist splint off

- ☐ Work
- ☐ Taking care of children, mokopuna/grandchildren
- ☐ Using computer, keyboard or mouse
- ☐ Using mobile phone or landline
- ☐ Community/volunteer
- ☐ Study/learning
- ☐ [ ] Other

9. Select any leisure activities/mahi ngahau you did today, where you did at least some of the activity with your wrist splint off

- ☐ Physical exercise
- ☐ Playing game; video, phone
- ☐ Playing game; board game/card game/puzzle
- ☐ Handcraft e.g carving, woodwork, drawing, knitting
- ☐ Social activity
- ☐ Writing cards/letters
- ☐ Music activity
- ☐ Cultural e.g. Marae
- ☐ Religious
- ☐ Creative
- ☐ Gardening/taking care of plants - mahi māra
- ☐ Learning
- ☐ Teaching whanau/mokopuna
- ☐ [ ] Other

10. Overall, how much did you use your hand/wrist today, during everyday activities, with your wrist splint off? *

0	1	2	3	4	5	6	7	8	9	10

Not at all — Most of the time

11. How difficult was it to do everyday activities with your wrist splint off? *

- ◯ Not at all difficult
- ◯ Moderately difficult
- ◯ Extremely difficult

12. On Mondays only, please respond to this statement
I'm afraid that I might injure myself if I exercise

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Strongly agree

Appendix L: Study III interview guide, initial iteration

Indicative questions for semi-structured interview

Question	Probes
Can you tell me about the exercises you were given to do?	What sort of information or advice did you get about exercises? Tell me about what is is like doing the exercises. Are there times in the day that you stop to do exercises? What kinds of things help you remember? Sometimes as hand therapists we give out exercises like a prescription - "you must do this many exercise, this often". If that was your experience, how was that for you? In what ways did the exercises help/not help your recovery? Let's look at your exercise/activity log. Explore with person.
I'm interested in learning about your everyday activities.	What are the activities that you do daily/weekly? How are these important to you? (explore meaning/pupose/utility) What kinds of activities do you usually do for enjoyment? What kind of advice was given to you by your surgeon and hand therapist about doing everyday activities?
I'd like to dig a bit deeper into your everyday activities over the past feww weeks. What kinds of things have you been doing each day?	It can be hard to remember - we can use your daily log Thinking back to when you first started moving your wrist, what were the things you tried to do first without your splint on? What was that like? I'd like to know more about what you thought about using your hand with your splint off As the days went by were you able to do more activities? Explain. What kinds of things did you do by week four and five? Were there ways that you changed certain activities so you could still do them? Can you give me some examples or show me?
For the next few questions I'd like to talk about how easy or hard it's been to do everyday activities and how you decided what to do.	I mentioned earlier that we don't always give very specific instructions about which activites are ok to do. I'm interested in how you decided what you could do, especially without your splint on? Were there things that held you back from doing certain activities? Were there things that helped you to feel more confident about doing certain activities? Patients sometimes say to me that they're worried that using their hand, without the splint, will hurt the bone. What do you think about this? My patients sometimes use words like I'm scared or it's not safe to lift things or it's too hard to do …, I'll wait till I get better to try that. Was it like that for you? Did you discuss your concerns with your therapist or doctor? What kinds of things did they say? How helpful was that advice? Are there things that would have helped you to feel more ok about doing everday activities?
Now I want to talk about the things that helped you get your movement back in your hand and wrist.	I have this idea that doing everdyay activites can be a kind of therapy for your wrist. What do you think about that?

	Looking back over the past few weeks, can you think of any activities you might have used as a way of 'exericsing' your wrist? Can you explain further? I notice that you have really great movment in your fingers and wrist. What were the best things you did to get your movement back or I notice that your wrist is (fingers are) very stiff – how is that for you?
Thinking about specific activities. Could you think of activities that could be used as part of a therapy programme?	In the future I'd like to incorporate everyday activities into home programmes for people with your injury. What do you think about this? Using activities as therapy. I'm interested on what kinds of activities best promote wrist movement? Are there specific kinds of activities you think do that? What kinds of activities motivated you to use your hand/wrist? Can you tell me why? Explore motivational value Other people have suggested these activities*, what do you think? What would you put on this list?

General prompt questions

Can you expain what you mean by…?
Are you able to give an example?
Tell me more about…?
What was it like for you when…?
You mentioned earlier that …. I'd like to know more about why you thought
Some of the other participants have mentioned… is this something that's been the case for you?

*e.g. writing, getting dressed, brushing hair, folding clothes, lifting items from a high shelf, playing cards or a board game, light gardening, typing on a keyboard/using a mouse, pouring from a jug into a cup, using a mobile phone, light cleaning

Appendix M: : Study III interview guide, later iteration

The naïve enquirer

As you know this study is about finding out about your recovery from surgery and the ways you're getting the movement back in your hand and wrist. I want to learn about the ways that everyday activities have been part of your recovery. We don't really know much about this. I'm here to explore your experiences and find out about your journey.

Can you tell me about your recovery so far, what things have been surprising or unexpected? Explore/delve

Can you think back to a day or time when you first started using your wrist out of the splint. Describe the day/time. What was it like for you?

Can you tell me about your wrist injury now. How did it happen and what impact has it had on the things you do

Tell me about what you've been doing this morning? And what about what you're not doing - What's holding you back?"

Listen for emotion and use the language of the participant

Get to the depth of the story, the emotion behind what's being said

Earlier on you said that … was fun (or … or ….) – tell me about feeling proud …

What were you thinking about when you…?

What were you feeling when you…?

Why do you think it happened like that?

What was it about ….. that ….?

Question	Probes
Set the scene Background Get to know person	
advice aboout activities	**Advice given** by surgeon and hand therapist about activities? Other competing information e.g. other therapies, family Helpful/made sense etc
Exercises	What sort of information or advice did you get about doing exercises? Were there things you liked and didn't like about the exercises? How long did it take to do an exercise session – how many did you do during the day? Effect of exercises on stiffness. Types? How long did you keep the exercises up for – why did you reduce?
I'd like to dig a bit deeper into your everyday activities (*parameters)*	Look at the log – explore progressions what were the things you tried to do first without your splint on? How did it feel for you? Morning/middle of the day/evening I'm interested in how you decided what activities to do? Were there things that held you back/helped
Can you tell me what it was like doing activities without your splint on? *(experiences)*	Explore how easy/hard it was/feelings Influence of **enjoyment**. What it's like when you were doing something you enjoyed? What about things you felt needed to be done? How did pain influence you? **Familiarity** of movement during activity, **automaticity – did it feel different from activities**
I'd like to talk about your *perceptions* (thoughts) on using everyday activities as part of your 'therapy'	What about, the everyday activities that have **meaning** or importance? **Motivational value** One of the things I'd like to explore is about movement and activity: Perceptions around **whether activities promote movement** Overall movement **dosage** during the day
Thinking about specific activities. Could you think of activities that could be used as part of a therapy programme?	What would your ideal rehab look like? What do you think about everyday activities being part of you your '**therapy'** or rehabilitation? Can you think of any activities you might have used as a way of 'exericsing' your wrist? Are there activities that promote wrist movement better than others? Types of **activities** that were used to promote movement I'd like to **look at your activity log,** can you explain to me exactly which activities you did and how you did them?

How challenging/difficult was it to do everyday things? How did you determine the right challenge? Do you need 'activity guidelines?

Let's explore that idea of … the just right challenge, where you had to make a decision about whether to do something without your splint on. Describe what you did – talk through the process.

Other people have commented that using your wrist is not enough to exercise it to the extremes of movements – what do you think about that?

Can you think of a time when you did something you enjoy – describe the event.

How the wrist felt when first using/moving it – sensations, emotion, hesitancy. Describe a time Let's explore that a bit more. First experiences with doing

What did your wrist feel like in the cast/splint –

How decisions were made about splint wear or not

Do you think there are some ways we could build in 'everyday doing' into part of hand therapy. How could we utilise the benefits of 'moving while doing'. Discuss activity based intervention.

The concept about the memory of movement – the idea that your wrist will know what to do

Explore concepts of 'light' and 'heavy' activities – what does that mean. Give some examples

If you think that all the daily activities help why do you think this – why do you think they help, what it is about the 'doing' in your daily life that contributed to your recovery. In what ways? Try and get to building of confidence/efficacy, mood, enjoyment, ability to do everyday life, reducing anxiety, feeling better etc

Do people feel better because they are occupied/doing – how/why

Explore some more the concepts of motivation and how meaningful occupations provided a structure to the day/a way of reversing the imbalance that occurs after injury – i.e. why it was so important to re-establish routines, re-engage/how being engage or absorbed in an activity might encourage sustained movement

Finish with, is there anything you want to tell me? Give time to respond

Appendix N: Study III AUTEC letter of approved amendments 23 April 2020

Auckland University of Technology Ethics Committee (AUTEC)

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

23 April 2020

Valerie Wright-St Clair
Faculty of Health and Environmental Sciences

Dear Valerie

Re: Ethics Application: **19/224 Patient perspectives on recovery of wrist motion after surgery for distal radius fracture**

Thank you for your request for approval of amendments to your ethics application.

The following amendments to the data collection protocols are approved

- consent to be obtained via email or verbally;
- collection of demographic data via phone, email, zoom or skype;
- semi structured interviews via phone, zoom or skype

Note: For participants without the ability to scan or send an image of the signed Consent Form, the content of the Consent Form can be copied into an email and sent to the researcher with a sentence indicating their agreement. If this method of verifying consent is used, it is important that the email is clearly from the participant.

Non-Standard Conditions of Approval

1. If your use an oral consent protocol, you will need to note the location of the consent recording, either on video or audio, and then separate this from the interview data and store it separately.

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to be submitted to or reviewed by AUTEC before commencing your study.

I remind you of the **Standard Conditions of Approval**.

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted. When the research is undertaken outside New Zealand, you need to meet all ethical, legal, and locality obligations or requirements for those jurisdictions.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: juliecollis@gmail.com; nada.signal@aut.ac.nz

Appendix O: Study III Patient Rated Wrist and Hand Evaluation (PRWHE)

Name: ______________________________ Date: ____________

PATIENT RATED WRIST/HAND EVALUATION

The questions below will help us understand how much difficulty you have had with your wrist/hand in the past week. You will be describing your ***average*** *wrist symptoms* ***over the past week*** *on a scale of 0-10.* Please provide an answer for **ALL** questions. If you did not perform an activity, please **ESTIMATE** the pain or difficulty you would expect. If you have **never** performed the activity, you may leave it blank.

1. PAIN

Rate the average amount of pain in your wrist/hand over the past week by circling the number that best describes your pain on a scale from 0-10. A zero (0) means that you did not have any pain and a ten (10) means that the pain is the worst possible (i.e worst you have ever experienced or that you could not do the activity because of pain).

RATE YOUR PAIN:	None										Worst
At rest	0	1	2	3	4	5	6	7	8	9	10
When doing a task with a repeated wrist/hand movement	0	1	2	3	4	5	6	7	8	9	10
When lifting a heavy object	0	1	2	3	4	5	6	7	8	9	10
When it is at its worst	0	1	2	3	4	5	6	7	8	9	10

How often do you have pain?	0	1	2	3	4	5	6	7	8	9	10
	Never										Always

2. FUNCTION

A. SPECIFIC ACTIVITIES

*Rate the **amount of difficulty** you experienced performing each of the items listed below - over the past week, by circling the number that describes your difficulty on a scale of 0-10. A **zero** (0) means you did not experience any difficulty and a **ten** (10) means it was so difficult you were unable to do it at all.*

	No Difficulty										Unable To Do
Turn a door knob using my affected hand	0	1	2	3	4	5	6	7	8	9	10
Cut meat using a knife in my affected hand	0	1	2	3	4	5	6	7	8	9	10
Fasten buttons on my shirt	0	1	2	3	4	5	6	7	8	9	10
Use my affected hand to push up from a chair	0	1	2	3	4	5	6	7	8	9	10
Carry a 10lb object in my affected hand	0	1	2	3	4	5	6	7	8	9	10
Use bathroom tissue with my affected hand	0	1	2	3	4	5	6	7	8	9	10

B. USUAL ACTIVITIES

*Rate the **amount of difficulty** you experienced performing your **usual** activities in each of the areas listed below, over the past week, by circling the number that best describes your difficulty on a scale of 0-10. By "usual activities", we mean the activities you performed **before** you started having a problem with your wrist/hand. A **zero** (0) means that you did not experience any difficulty and a **ten** (10) means it was so difficult you were unable to do any of your usual activities.*

Personal care activities (dressing, washing)	0	1	2	3	4	5	6	7	8	9	10
Household work (cleaning, maintenance)	0	1	2	3	4	5	6	7	8	9	10
Work (your job or usual everyday work)	0	1	2	3	4	5	6	7	8	9	10
Recreational activities	0	1	2	3	4	5	6	7	8	9	10

APPEARANCE- OPTIONAL

How important is the appearance of your hand? ☐ Very Much ☐Somewhat ☐ Not at all

Rate how dissatisfied you were with the appearance of your wrist/hand during the past week.

0 1 2 3 4 5 6 7 8 9 10

No Dissatisfaction — Complete Dissatisfaction

Any other comments?

Score: /100

Scoring: sum of 10 disability items divided by 2 plus sum of 5 pain items

Appendix P: Study III Tampa Scale of Kinesiophobia (TSK) questionnaire

Tampa Scale-11 (TSK-11) **Name:** **Date:**

This is a list of phrases which other patients have used to express how the view their condition. Please circle the number that best describes how you feel about each statement.

	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
1. I'm afraid I might injure myself if I exercise.	1	2	3	4
2. If I were to try to overcome it, my pain would increase.	1	2	3	4
3. My body is telling me I have something dangerously wrong.	1	2	3	4
4. People aren't taking my medical condition serious enough.	1	2	3	4
5. My accident/problem has put my body at risk for the rest of my life.	1	2	3	4
6. Pain always means I have injured my body.	1	2	3	4
7. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening.	1	2	3	4
8. I wouldn't have this much pain if there wasn't something potentially dangerous going on in my body.	1	2	3	4
9. Pain lets me know when to stop exercising so that I don't injure myself.	1	2	3	4
10. I can't do all the things normal people do because it's too easy for me to get injured.	1	2	3	4
11. No one should have to exercise when he/she is in pain.	1	2	3	4

Appendix Q: Study III published article: An Interpretive Description study of perspectives on the influence of daily activities and occupations on recovery from a surgically repaired distal radius fracture

DISABILITY AND REHABILITATION
https://doi.org/10.1080/09638288.2021.1936219

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

OPEN ACCESS Check for updates

"The more I do, the more I can do": perspectives on how performing daily activities and occupations influences recovery after surgical repair of a distal radius fracture

Julie M. Collis[a], Elizabeth C. Mayland[b], Valerie Wright-St Clair[a,c] and Nada Signal[d]

[a]School of Clinical Sciences,Auckland University of Technology, Auckland, New Zealand; [b]School of Health and Society, University of Wollongong, Wollongong, Australia; [c]Centre for Active Ageing, Auckland University of Technology, Auckland, New Zealand; [d]Health & Rehabilitation Research Institute, Auckland University of Technology, Auckland, New Zealand

ABSTRACT

Purpose: The study aimed to explore perceptions and experiences about how engaging in daily activities and occupations influenced recovery in the first eight weeks after surgical treatment of a distal radius fracture.

Methods: Twenty-one adults completed an online activity and exercise log then participated in a semi-structured interview between weeks 6 and 8 postoperatively. Interviews were transcribed and analysed using reflexive thematic analysis.

Results: Daily activities and occupations were highly influential in facilitating recovery of movement and function of the operated limb. Five themes provided an understanding of how occupation operated to promote recovery. Occupation was (i) a primary driver of the rehabilitative process, providing an impetus for recovery, (ii) offered ready-to-hand challenges for opportunistic, automatic movement, (iii) invited intentional use of the affected wrist, (iv) habituated the wrist to movement through repetition and confidence-building, and (iv) drew on psychosocial resources to enable reengagement with life activities and roles.

Conclusions: Incorporating the performance of graded, modified activities during the early weeks of rehabilitation creates opportunities for wrist movement, enhances wellbeing, and assists in the habituation of wrist movement. Activities and occupations can be used as a therapeutic strategy to promote recovery from surgical treatment of a distal radius fracture.

ARTICLE HISTORY
Received 4 February 2021
Revised 23 May 2021
Accepted 24 May 2021

KEYWORDS
Distal radius fracture; occupation; qualitative interpretive description; rehabilitation; activities of daily living; reflexive thematic analysis

IMPLICATIONS FOR REHABILITATION

- Rehabilitation after surgical repair of distal radius fractures has traditionally focused on exercise routines.
- Daily activities and occupations can also be used to promote wrist movement and function during the early weeks of rehabilitation.
- Occupation is a naturally occurring source of wrist movement, motivation, and wellbeing that can be harnessed for therapeutic advantage after surgical repair of distal radius fractures.
- Therapists can collaborate with patients to select and modify daily activities and occupations to incorporate into early postoperative therapy programmes.

Introduction

A fracture of the distal radius is a common upper extremity injury frequently treated by surgical repair, followed by wrist mobilisation within two weeks of surgery [1]. Wrist stiffness, pain, and functional or sensorimotor impairment can persist after surgery [2–4] and rehabilitative strategies that address impairment and promote early recovery are needed. Wrist and forearm exercises are routinely used during early rehabilitation to promote movement [1,5]. Performance of daily activities can also be used but is poorly defined as a rehabilitative strategy and not as widely promoted as exercise interventions [6]. One of the barriers to occupation-based interventions is a lack of knowledge about how occupation facilitates recovery from injury [7,8]. Without such understandings it is difficult to design interventions that capitalise on the benefits of occupation.

In this study, occupation refers to the broad categories of daily life engagements by which people occupy themselves: daily living activities, rest, education, work, leisure, and social participation [9]. Occupation assumes meaning, purpose, intentional engagement and that occupation is contextualised within daily life [9]. The term activity is used differentially to refer to the smaller actions or sets of day to day living tasks that occupations are constructed from [9,10]. Performance of activities and occupations may facilitate recovery in ways distinct from exercise routines such as augmenting movement quantity and quality [8,11], enhancing motivation, and facilitating functional movement [8].

CONTACT Julie M. Collis Julie.collis@aut.ac.nz School of Clinical Sciences, Auckland University of Technology, Auckland, New Zealand

Supplemental data for this article can be accessed here.

This article has been corrected with minor changes. These changes do not impact the academic content of the article.

It was considered that performing daily activities may be an underutilised rehabilitative strategy. The questions were raised: what role does activity and occupation play in the recovery from distal radius fracture surgery, and how might occupation be harnessed to form a therapeutic intervention?

The Medical Research Council recommends that intervention development may require primary research to identify how that intervention is likely to produce change [12]. A study was therefore designed to explore the perceptions and experiences of people about how engaging in daily activities and occupations influenced recovery in the first eight weeks after surgical treatment of distal radius fracture.

Methods

A qualitative study using interpretive description methodology [13] and underpinned by a critical realist perspective, was undertaken. The Standards for Reporting Qualitative Research (SRQR) [14] were used to inform the design of the study. The study was approved by the Auckland University of Technology Ethics Committee (AUTEC) on 29 July 2019, number 19/224. In this paper, the term "therapist" refers to an occupational, physical, or hand therapist involved in the rehabilitation of upper extremity injuries.

Interpretive description is a qualitative methodology where researcher and participant work together to generate knowledge about clinical phenomena [15,16]. Critical realism guided the philosophy of the study by accepting that an objective, knowable reality exists but rejecting that the notion that observed phenomena can be understood exclusively through stringent scientific methods [17,18]. The imperative for researchers guided by critical realism is to explore mechanisms and contexts, to understand not only if something works, but how it works [17,19]. Interpretive description focused the study firmly on clinical practice and critical realism provided a cohesive overarching framework.

Study setting and participants

Participants were recruited through private and public hand therapy clinics in Auckland, New Zealand. Figure 1 details the recruitment procedures. Potential participants were selected based on predetermined inclusion criteria (Table 1) and purposive sampling criteria (age, gender, ethnicity, pain, kinesiophobia, and finger stiffness), in order to obtain maximum variation of participant characteristics. A sample of 20–30 was estimated based on the concept of information power, where fewer participants are needed in a study with high information power [20]. We achieved high information power through a tightly defined aim, targeting participant characteristics, applying established theory, and rich dialogue and analysis [20].

Data generation

Data were generated via an activity and exercise log and a semi-structured interview. Participants were visited on two occasions (see Figure 1). The clinical features of pain severity and kinesiophobia were measured by the patient rated wrist and hand evaluation (PRWHE) [21] and the Tampa scale of kinesiophobia-11 (TSK-11) [21,22], respectively. The TSK-11 has a score range between 11 and 44 with a score of $\geq$35 delineated as high kinesiophobia [23]. Wrist stiffness was scored as: $>$50%, 20–50%, or $<$20% of the contralateral side [24]. Finger stiffness was a fingertip to distal palmar crease measurement $>$ 1cm [2].

Activity and exercise log

Between weeks two and six postoperatively, participants were asked to complete an online activity and exercise log (supplementary file 1). The purpose of the log was as a prompt for discussion during the interviews and to observe the types and range of activities that individuals performed. The log was developed from research that defined valued occupations and functional problems for people with hand injuries [25–27]. Initially, participants were asked to complete the log daily; this was amended to two to three times per week as the first few participants indicated that daily completion was repetitive.

Semi-structured interview

The interview was conducted between weeks six and eight postoperatively. The interviews were a semi-structured exploratory style [28]. An interview guide was developed around four broad areas: experiences of daily activities, perceptions on the influence of daily activities on recovery, advice/education received about activities and the pragmatics of activity performance. The questions were open-ended and provided a framework only for the interviews. This approach allowed the interviewer to probe and to explore responses at a deeper level in accordance with interpretive description research [29].

Data processing and analysis

All interviews were audio-recorded and transcribed verbatim by a professional transcriber and checked for accuracy by the first author (JC). The data were analysed using reflexive thematic analysis, a six-phase inductive style of analyses that draws themes from the data [30,31]. Familiarisation was conducted by the first author through reviewing the audio recordings and transcripts. Codes were then generated inductively from the data, by (JC), using both descriptive and interpretive labels. NVivo 12 was used for the coding process. Following the completion of coding, theming commenced. First, candidate themes were developed, then discussed and finalised, based on agreement between all authors. Themes were subsequently named and defined.

Study rigour

The research team consisted of experienced therapists and academics. The first author (JC), an occupational and hand therapist, led data generation, coding, and development of themes and was not involved in the clinical care of any participant. Cross-verification was achieved through the research team reviewing sections of data and confirming codes and final themes. Quality and rigour were promoted through a collaborative, reflexive approach. Epistemological integrity was achieved by framing the study within a critical realist ontology and interpretive description method. The steps of reflexive thematic analysis were followed to ensure a rigorous analytic process. It was acknowledged that the primary researcher may bring theoretical allegiances or professional assumptions that could influence the research [14,31]. A presuppositions interview was conducted by senior researchers (VW and NS) prior to data collection. During the interview, the primary researcher was questioned about assumptions and challenged to remain reflexive and alert to narratives that may reveal hidden meanings.

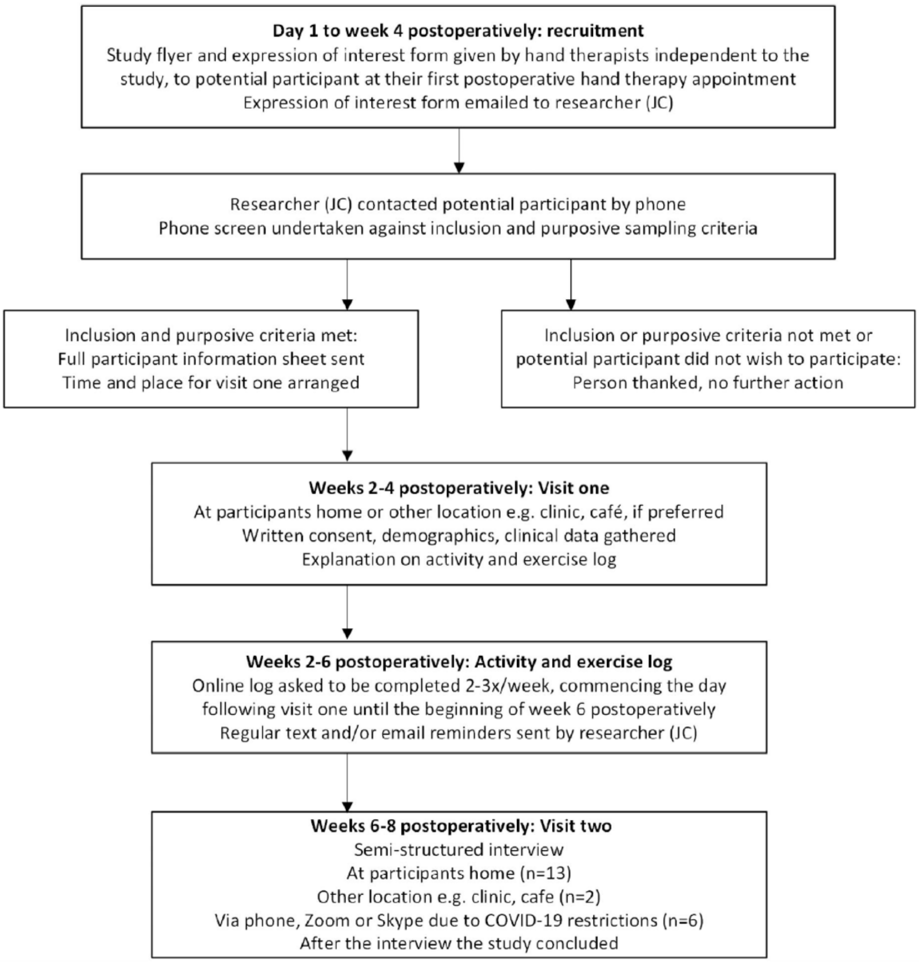


Figure 1. Study flowchart.

Table 1. Eligibility criteria.

Inclusion
Aged over 18 years
Surgical fixation of distal radius fracture, all fracture AO types A, B, or C
Less than four weeks postoperative at time of recruitment
Stable fixation, deemed by surgeon to be suitable for mobilisation by four weeks
Conversational English
Exclusion
Concomitant fracture of another bone (excepting ulnar styloid)
Concomitant surgery for injury of other tissues: tendon, muscle, nerve
Any condition or injury that significantly affects normal use of the operated limb
Patients undergoing hand therapy by primary researcher

Results

During 2019 and 2020, 21 adults participated in the study. Participant characteristics are summarised in Table 2 and detailed in Table 3.

The activity log was completed an average of nine times (range 3–23). The majority of participants commenced the log by the end of week three ($n = 14$) and the remainder during the following two weeks. The log and interviews revealed a broad range of activities performed without a splint during the first six weeks (Table 4). All participants were provided with a removable wrist splint (custom thermoplastic or off-the-shelf) at the time of mobilisation. The log showed that by the end of week three postoperatively most participants (14/21), were using their wrist during activities such as eating, showering, or grooming. Of those 14, many were also using their wrist during meal preparation, or household tasks. By the end of week, six all participants were performing some personal, home, work, or leisure activities involving their operated wrist without a splint.

Interviews revealed that for most participants, daily activities and occupations were highly valued for facilitating recovery of movement and function of the affected limb. We generated five themes that elucidated how occupation acted as an agent of

Table 2. Summary of participant characteristics.

Variable	Number (percentage) or mean (range)
Gender: female	14/21 (67%)
Age	53 (28–74)
Ethnicity: Māori	3/21 (14%)
New Zealand European	14/21(67%)
Other (Indian, Russian, Afghani)	4/21 (19%)
Dominant hand injured	10/21 (48%)
Finger stiffness at visit one (>1 cm ADPC)	11/21 (52%)
Wrist stiffness at visit one (moderate or severe)[a]	16/21 (76%)
Pain at visit one (PRWE pain sub-scale)	25/50 (10–41)
Kinesiophobia (TSK-11)	25/44 (12–42)
TSK-11 ≥ 35[b]	2/21 (10%)
Fracture type: comminuted, intraarticular	19/21 (90%)
Ulna styloid fracture	8/21 (38%)
Volar locking plate	20/21 (95%)
Fragment-specific fixation	1/21 (5%)
Additional surgical procedure (2× carpal tunnel release)	2/21 (10%)
Number of days from surgery to mobilisation	13 (7–27)
Number of days from surgery to interview	53 (44–64)
Number of activity log entries	9 (3–23)

ADPC: active distal palmar crease; PRWE: patient rated wrist and hand evaluation; TSK: Tampa scale of kinesiophobia.
[a]20–50% (moderate), <20% (severe) range of movement of the contralateral side [31].
[b]A TSK score of >35 is indicative of high kinesiophobia [30].

Table 3. Characteristics of participants.

Participant	Gender	Age	Injured side	Occupation	Intra-articular fracture	Surgical procedures	Finger stiffness[a] at visit 1
Paul	Male	55	Non-dominant	Handyperson, builder	Y	Fragment-specific fixation (radial, dorsal, ulna plates); CTR	Y
Farida	Female	50	Non-dominant	Storeperson	Y	Volar plate	N
Graeme	Male	46	Dominant	Plumber	Y	Volar plate	N
Angela	Female	51	Dominant	Homemaker	N	Volar plate	Y
Natalya	Female	59	Non-dominant	Homemaker; administrator	Y	Volar plate and interfragmentary screw	Y
May	Female	32	Dominant	Landscape gardener; parent	Y	Volar plate	N
Ian	Male	55	Dominant	Manager; administrator	Y	Volar plate and radial pin plate	N
Layla	Female	34	Dominant	Parent	Y	Volar plate	N
Awhina	Female	49	Dominant	Driver	Y	Volar plate	Y
Zoe	Female	68	Non-dominant	Retired	Y	Volar plate	Y
Bill	Male	72	Non-dominant	Retired	Y	Volar plate	Y
June	Female	74	Non-dominant	Retired	Y	Volar plate	N
Kukurei	Female	56	Non-dominant	Music teacher	N	Volar plate	N
Karen	Female	57	Non-dominant	Nurse	Y	Volar plate	Y
Santosh	Male	30	Dominant	Driver	Y	Volar plate	N
Marie	Female	71	Dominant	Retired	Y	Volar plate	Y
Silky	Female	71	Non-dominant	Retired	Y	Volar plate	N
Dina	Female	28	Non-dominant	Parent	Y	Volar plate and ulna styloid screw	Y
Alexa	Female	36	Dominant	Parent; manager	Y	Volar plate and radial pin plate; CTR	Y
Trent	Male	62	Dominant	Handyperson	Y	Volar plate	Y
Nick	Male	55	Non-dominant	Designer	Y	Volar plate and dorsal pin plate	N

CTR: carpal tunnel release.
[a]Fingertip to distal palmar crease measurement > 1 cm.

change in promoting recovery from surgical treatment of distal radius fracture. Quotes that are highly illustrative of the themes are presented. They are identified by participants' pseudonyms, ages and whether they injured their dominant (DHI) or non-dominant hand (NDHI). An overview of the themes is given in Table 5.

Theme one: occupation is a driving force of recovery

> I just want life to go back to how it was. To be able to take the boat out and go fishing and ride my bike and stuff like that. Graeme, 46, DHI

Theme one describes how the desire to return to valued occupations and life roles provided a potent impetus and focus for the recovery process. The disruption to daily life and usual activities and occupations was unwelcome. Participants expressed a strong need to reclaim independence, participate in usual life roles and return to valued occupations. Engaging in daily activities helped to reclaimed normality and wellbeing.

Experiencing disruption

> Like I said, it's not until it didn't function, you realise how much you do use your hand. Awhina, 49, DHI

Most participants talked about how routine activities previously carried out with little thought, such as getting dressed or making breakfast, were suddenly noticed and became sources of frustration, discomfort, and challenge. Many people expressed feelings of being lazy, or a burden. Others missed the "ordinariness" of daily life and described the sudden loss of "doing" as making them feel bored or lost.

Table 4. Activities and occupations performed by participants in the first six weeks with the wrist splint off and involving at least partial use of the affected wrist.

Applying make-up, face, or hand cream	Opening cupboards, drawers, containers
Baby care, e.g., diapers	Personal care, e.g., shaving, brushing teeth
Childcare: dressing, pushing a pushchair	Pet care: feeding, grooming
Carrying light items, e.g., a plate, lunch bag	Playing a musical instrument
Chopping, peeling vegetables	Playing video games
Cooking, e.g., making breakfast or a salad	Sewing, using a sewing machine
Driving	Showering – washing and drying self
Eating, drinking	Swimming
Gardening, e.g., weeding	Tidying up children's toys
Getting dressed, doing up shoelaces	Turning controls on kitchen appliances
Handcrafts	Unpacking and putting away shopping
Having a bath	Using a keyboard and/or computer mouse
Housework, e.g., tidying, making beds	Using a remote control
Laundry: hanging up, folding, putting away	Vacuuming
Loading, unloading the dishwasher	Washing and drying dishes
Making a cup of tea or coffee	Washing, doing hair
Making roti	Watering the garden
Mopping the floor	Wiping benches

Table 5. Five themes showing how activities and occupation influenced recovery from surgical treatment of a distal radius fracture.

	As a driver of recovery	Disruption to daily activities was experienced negatively
		Disruption motivated reengagement
		Daily activities were used to reclaim normality and enhance wellbeing
	Through offering ready-to-hand challenges	Daily activities were a ready source of automatic movement
		Daily activities had built-in gradations and challenges
Occupation operated	By inviting intentional doing	Intentional, conscious "doing" was needed
		Mindful strategies were used to enable performance of activities
	To habituate the wrist to movement	Initial movement felt unnatural
		Activity performance normalised wrist movement
		Self-efficacy and confidence were enhanced by engaging in occupation
	Through drawing on psychosocial resources	Strength was gained from psychosocial resources
		Wellbeing practices were used to facilitate reengagement with valued occupations

> Yeah, I'd get frustrated. Very frustrated. I'm not used to sitting still. I'm used to getting up and going. Silky, 71, NDHI

There was a common experience that the interruption to everyday "doing", negatively affected mood and wellbeing and some participants expressed fears about the future.

> I was worried about what am I gonna be able to do again. I did ballroom dancing and I was like always one day I thought to get back into it again and I was like, "Am I gonna be able to do it again?" "What am I gonna be able to do?" "How much movement am I gonna have?" Just those sorts of things. "What is my life gonna be like?". "When can I pick up my son?". Alexa, 36, DHI

Reclaiming normality

The difficulties experienced motivated people to begin "doing" again and use their affected hand. Initially, this was often for simple functional activities, then later for work and recreational pursuits.

> When I first tried to do it, it was like, "Oh my god, I can't even hold a cup of coffee." And it frustrated me so I got to the stage where I slowly built up so I could, over five days hold it and lift it. Graeme, 46, DHI

> We enter in a lot of things. Netball. Iron Māori. Amazing Race. But I couldn't even do the training. They wouldn't have me. It's like you've been outcasted … but it made me work harder. It made me wanna hurry up. Awhina, 49, DHI

The need to re-establish normal routines and independence was expressed strongly. Some people described inactivity as being so foreign that the natural thing to do, was "do". Even if it meant taking more time or finding alternative methods, the very act of doing seemed to help combat the disorienting effect of the injury.

> I think being able to do those things such that you are functioning in some degree of independence, I think that's important. Yeah, I think that's hugely important. Well it was for me anyway. I hated the dependency. Absolutely loathed it. So, to be able to do those things and even if it took me forever, on simple tasks to start with, those kind of things were important. Zoe, 68, NDHI

Engagement in meaningful occupations was seen to boost mood and wellbeing. Participants described feeling more settled when "doing", that gardening lifted mood, or helping with household management negated feelings of laziness and uselessness. For some, starting to perform daily activities shifted the focus from "I can't" to "I can" providing a sense of optimism and hope.

> Just to see the light at the end of the tunnel, to know that I'm gonna be able to use my hand. And to know that things will … come back to normal and … I'm gonna get better and I will get stronger and I will be able to function properly again. Well maybe not function, but I'll be able to do the things I want to do. Nick, 55, NDHI

Theme two: occupation offers ready-to-hand challenges

> I thought well … I just have to work it out. You just have to work it out. There's nobody else here to do it for you, so you have to do it. If you don't do it, well you don't get any taties [potatoes] Silky, 71, NDHI

This theme describes how activities and occupations promoted recovery through being ready and available. Activities and occupations were an intrinsic part of daily life thereby offering a naturally occurring source of movement and challenge. Activities were observed to have inbuilt gradations that created stepwise challenges for wrist movement.

A ready source of movement

> The thing is that if I do anything, it's not that I think of it, it's just that I do it. That's just offhanded probably. You need to do it, do it. You don't even think like that, it's just such a natural thing. Bill, 72, NDHI

The embedded existence of occupation in daily life was perceived to create a naturalistic opportunity for movement; in a sense, movement was a by-product of "doing". Occupation offered challenge in ways different from exercise routines. Exercises were done at specified intervals during the day and performed with focus. Activities and occupations, on the other hand, were thought to promote a more automatic type of movement that occurred opportunistically throughout the day as tasks that needed to be done presented themselves.

> So, when I go to change dishwasher, I need to do it. I don't think it will develop my hand, I just set my mind that I need to come back to my usual duties and I think it's a normal thing. I don't think that it will be bending better … I do duties … and hand develop. Natalya, 59, NDHI

Some participants noticed a naturally occurring rhythm of movement during activity that took their focus away from pain or discomfort.

> Once you start doing what you enjoy, even if you do get little twinges here and there, you totally forget about it. You don't really pay any attention to it. If you keep doing whatever you enjoy and keep using your wrist, after a while you don't pay any attention to any little pain you get. Farida, 50, NDHI

A natural stepwise challenge

Daily activities were perceived to offer challenges for movement that happened in a stepwise process. Participants started with simple tasks that involved minimal load or demand on wrist motion and progressed to greater challenge over time. Frequently people started activity performance by just using the fingers of the affected hand.

> Even if I had the brace on and I wasn't confident with what was going on in my wrist, I'd still very much use my fingers. I was typing. Using the mousepad on my computer. Using my fingers to open, trying to open packets and yeah definitely using my fingers. Trent, 62, DHI

Over time the wrist would be included for more of the activity and a broader range of activities were introduced. Sometimes, this was a conscious process but often occurred with little thought, people simply noticed that they were using their wrist for increasingly challenging tasks.

> I was conscious that it was changing very quickly day by day to sort of add a little bit more on each day and try something different. Maybe I couldn't do something one day, but I could do it the next day. Opening the shampoo bottle. I couldn't do it one day. Could do it the next day. Did it every day after that. Just things like that, you just kind of add what you can do to your repertoire and then just look for other things that you can do with it. Ian, 55, DHI

Theme three: occupation invites intentional doing

> I want to get back to automatically using my right hand without thinking. And I think that to do it consciously, first of all, is the first step in doing that. Marie, 71, DHI

In this theme, the influence of occupation on recovery is by intentional engagement. In contrast to theme two where movement occurred instinctually, it was perceived that deliberate choices were made to perform activities in order to promote movement, strength, and function. Mindful decisions were made about how to perform an activity.

Intentional use of affected wrist

Participants for the most part perceived that they needed to make a conscious choice to use their affected hand in order to make progress. There was a common perception that daily activities played a significant part in restoring movement and strength.

> But yeah in terms of recovery, like I'm just very blown away by how well I've come along and yeah I certainly do believe that that bit extra that I've been doing with my wrist, changing nappies and chopping things and a little bit of gardening and that, I definitely think it's helped to get me where I'm at now with that movement. May, 32, DHI

Many people spoke about how they looked for opportunities to use their affected hand. There was a conscious seeking out of bilateral, challenging or unfamiliar tasks in order to intentionally promote use.

> But I made a real effort to try and do any fine stuff with my right hand. Your hand's been sitting around not doing anything for a while, it gets lazy, your left hand takes over. So there's a lot of things that I would try and do with my right hand. Making a cup of coffee. Maybe hold jars with my left hand and do the lid with my right hand and spoon it out with my right hand. Do the dials and knobs on the coffee machine with my right hand. Ian, 55, DHI

Most people noticed an immediate improvement in wrist movement and function once regular activity performance was initiated.

> You take the brace off, you do your exercises … and then put the brace back on. So … you're actually not using it a lot the rest of the time … And it's actually better to be able to use it all the time. I think, becoming easier because I'm using it all the time, rather than having it in the brace and only using it for little bits of the time. Angela, 51, DHI

Developing strategies to determine level of activity

Bounded by a desire to get better but not wanting to cause harm, participants used multiple strategies throughout the day to decide whether, and how to, perform an activity. People commonly used strategies such as tentatively trying an activity to test the wrist, simplifying an activity or only using their wrist as a support. Many times, participants discovered they managed better than expected thereby gaining confidence and a willingness to repeat an activity or try something harder.

> Well I thought I'd try. I thought, "Okay, I'll try and bath the dogs. If it doesn't work they can airdry." But they're pretty good so they just stand there. I don't have to really do a lot. So that was alright and then when I went to pull the weeds out, well if it wouldn't come and it just felt it wasn't going to come, I gave that away. I tried to do things and if it worked it worked. If it didn't it didn't. Silky, 71, NDHI

If an activity caused pain, discomfort, or fatigue this was taken as a cue to perform the activity in a different way or wait for a few days before trying again.

> When it felt like it was aching or tired I would just put the splint back on again. It wasn't out of it for that long, but probably, yeah definitely more than what they had suggested. May, 32, DHI

For some participants who were more fearful of movement, functional activity often resulted in pain and was taken as a cue to rest and wait.

> They [hand therapist] wanted me to start using it," but it was just too sore. Because as soon as you move it, all this starts hurting … I had it [the splint] off for a few hours, but man it hurt. And so after that I put it straight back on and kept it on. In my particular case it wasn't ready. Trent, 62, DHI

Many people relied on advice from health professionals to guide them about daily activities. While some participants received helpful education about daily activities, many said information was confusing, conflicting, or absent, and was perceived as an inhibitor of progress.

> When I came home, I kept thinking can I do this, or can I do that, like for example, can I chop the onion or can I cook or can I get a shower properly and use my hand? … I told myself to keep doing it anyway, 'cause no one told me to do it or not. They should explain if it's good for my wrist to do it, or if it's bad, then not to do it. Layla, 34, DHI, (paraphrased for understanding)

Some participants felt that using their wrist in the early weeks was too soon, others thought that everyday doing was an expected part of rehabilitation over and above exercises. Several participants however said that more direct advice on activity performance would have been helpful for enabling reengagement in daily life and for enhancing their recovery.

> I would say so. They pretty much just give you the hand exercises and that's it. And I think if they gave us on what we can do with that hand, where it's like if you're using your wrist you can flick your hand to make your bed or something. Something like that. I reckon that would help a lot. It'll make everyone's recovery faster. Dina, 28, NDHI

Theme four: occupation habituates the wrist to movement

> The more I do, the more I can do. Alexa, 36, DHI

Theme four describes how occupation facilitated recovery of automatic, instinctual wrist movement. Initial experiences with movement were often unpleasant and provoked apprehension. Performing daily activities acted to normalise wrist movement, build confidence, and progress the wrist toward unconscious use.

Experiences of moving and using

When participants began forays into wrist movement there were common experiences of apprehension and fear of causing harm. While some people felt confident to use the affected hand, most were cautious and took a tentative approach.

> Well it was a bit scary at first. The pain and that, yeah like I said it, didn't feel quite right to do, May, 32, DHI

Participants frequently described movement as feeling awkward, robotic, unnatural, or weird. Some people described that movement lacked spontaneity and had to be relearned. Other participants described unpleasant somatic sensations in the wrist.

> It just feels, instead of having elastic bands in there [the wrist], it feels as if you've got cord. Tight cord... it feels like there's, instead of nice stretchy rubber bands, someone's replaced those rubber bands with tight cords. Zoe, 68, NDHI

Many participants said that it required focussed effort to use the affected hand. There was a sense that the hand had become lazy and the non-injured hand would simply take over. Some were worried that if they did not force themselves to use the wrist, they might never recover full use.

> There was a resistance you know initially when I would do a task and sometimes you just kind of like feel lazy, want to use the other hand, which is more in motion. Santosh, 30, DHI

Alongside these negative experiences participants also liked moving the wrist again. There was a sense of relief at being able to use the wrist, often associated with a feeling of moving forward with rehabilitation.

> Once the brace was off, now it's just like, yeah instantly starting to, my brain was like, "Okay that is an available limb for use again." Alexa, 36, DHI

Activity performance normalised wrist movement

Woven through the interviews was a common noticing that the more an activity was repeated the easier and more familiar movement became.

> At first, I just couldn't do it. I was like oh my god, but then I just kept doing it and now I can. Karen, 57, NDHI

Participants often spoke about how initially they had to push themselves through some discomfort. There was an expectation that some degree of pain was inevitable but that by slowly pushing through pain, progress would occur.

> Initially when I'm doing a task, it's a bit painful and the resistance is there, so... I had to push myself a bit, so my wrist gets used to the situation. Like, if I brush my teeth or take shower... or apply the moisturiser, the resistance was there. But if I... overcame it with tolerating a bit of pain and pushing myself a bit... next time the wrist was used to the situation and ... it was better than before. Not so hard, I would say a bit easier. Santosh, 30, DHI

Many participants expressed the idea that repeating everyday activities had a positive effect on their confidence and self-efficacy. There was a noticing that succeeding with a simple activity was empowering and built confidence to try something more difficult.

> It seems to me that by finding out that you could do that, that you were kind of surprised and that you could do it, that builds a bit of confidence in terms of trying it again another time. Or trying something a little bit harder. June, 74, NDHI

Theme five: occupational reengagement draws on psychosocial resources

> I think it's a journey two ways. I think you've got a physical one and you've got a mental one. And if the mental one's not on board then you're not going forward either. Zoe, 68, NDHI

Theme five describes the concept that recovery required mental focus and a drawing on a range of psychosocial resources. Previous experiences, personal strengths, and wellbeing practices were harnessed to enable re-engagement with life activities. The theme encompasses the notion that both body and mind strategies were needed for the rehabilitation journey.

Personal strengths and previous experiences

Many people spoke about how they used positivity and optimism to overcome apprehension about moving and using the wrist. Other people described how determination would make them persist even when things were difficult.

> In some ways I think the recovery of my wrist is a lot to do with the attitude of stubbornness and pig-headedness. Bill, 72, NDHI

Many participants expressed a strong sense of self-belief about their ability to recover from the surgery. This often came from previous life experiences that had built hardiness and resilience such as growing up on a farm or being widowed. A number of participants spoke about their pragmatic, "just get on with it" attitude or a choice to focus more on the "can do's" and less on the "can't do's".

> I used to be able to do this so I can jolly well do it now. June, 74, NDHI

Recovery was not all about pushing the boundaries. Some participants said they had to adjust expectations and allow their body to do the work of recovery, that overly high expectations about recovery was not helpful.

> At the beginning I thought, "Why I cannot do this? It should be that I can do it". Now I stop thinking like that. Everything changed, I needed to reset my mind. And now it's much easier to accept what I can do and what I cannot do. I don't press myself. I have no expectations. I'm happier now. Natalya, 59, NDHI, (paraphrased for understanding)

Wellbeing practices

Participants also used wellbeing practices to cope with the injury and disruption to daily life. Some people used gratefulness to affirm their progress, some looked for the "silver lining" and others challenged negative ideas about pain.

> It was a little bit hard at first. The exercises were really sore, because I have to twist my hands everywhere. But I did it anyway because I was thinking, the more sore, the more it was good for me. After that I was

> able to do stuff and everyone says to me your recovery is so fast, because I kept using my wrist and was doing. Layla, 34, DHI

Other people expressed that exercise, good diet, and maintaining social interactions were beneficial for healing. Some used mindfulness practices such as meditation or listening to music. These participants spoke about how such practices helped to maintain a positive energy to the healing process.

> Absolutely. It has to be, doesn't it? If we're stressing about something and negative about it, then the healing's not gonna happen. And I kind of just intuitively know that with anything that we've really got to change our mindset, like I was doing meditations on healing and having a positive, sort of imagining it healed. I thought was very helpful. Kukurei, 56, NDHI

Discussion

Our study explored how engaging in daily activities and occupations influenced recovery in the first eight weeks after surgical treatment of distal radius fracture. Participant narratives suggested that occupation is highly influential in promoting recovery of movement and function after such surgery. Informed by the data, we outline a novel framework to elucidate how occupation acts to improve movement through acting as a driving force, offering ready-to-hand challenge, inviting intentional use, habituating the wrist to movement, and by drawing on the psychosocial resources of individuals. Our study deepens understandings of the remediating effects of activity performance in the early postoperative period. Insights that may challenge the traditional focus on exercise as the predominant therapeutic intervention are offered.

The study suggests two areas of focus for clinical practice: understanding occupation as an agent of change and viewing occupation and exercise as synergistically beneficial.

Occupation as an agent of change

We found that a key action of occupation in influencing recovery was by promoting both automatic and intentional wrist movement. While the idea that activities and occupation promoted wrist movement may seem an intuitive finding, we believe it provides a key to understanding occupation-based approaches. Unlike exercise routines which required focused attention and were performed intermittently, daily activities appeared to promote movement in low doses throughout the day. Participants also performed a broader range of activities than may be traditionally expected during the early weeks of recovery. The repeated wrist motion promoted through these activities may produce greater volume of movement than recognised and help to explain the benefits of approaches that include activity performance [6].

Some participants described a considerable wariness about activity due to advice about what they should not do rather than an enabling focus on what they could do. Recent literature has suggested that therapists may be more wary about daily activities than necessary after volar plating of a distal radius fracture [1], and the avoidance of activity early after surgery has been challenged [1,6]. In our study, participants performed a wide variety of activities, modifying the manner of performance according to postoperative timeframes and perceived capability. Participants made reasoned and agile decisions throughout the day about activity engagement, self-modulating their activity performance by using pain, fatigue common sense, and a "try-it-out" approach as a guide. Even participants that were less cautious, tempered their level of activity engagement in order to avoid pain and swelling.

It is important to remember that the risk of harm from underuse is likely much greater than that of overuse [32]. Poor self-efficacy and kinesiophobia are predictors of worse outcomes after distal radius fracture [32,33]. Interventions that promote self-efficacious behaviours are advocated as a way of avoiding disuse and fear-avoidance [32, 34]. Achieving mastery of small activities early after surgery may help to mitigate guarding and kinesiophobia [35], promote early self-efficacy, and create a platform for introducing progressively more challenging activities.

In our study, splint use was highly variable between participants and over time, and this may have influenced wrist stiffness and pain. Some participants reported that splints were appreciated for support and pain relief but many disliked splints because they impeded movement. Frequently, participants removed the splint simply to enable them to carry out daily activities and allow uninhibited wrist movement. The decision as to whether to remove a splint appeared to be based on varying postoperative advice and the degree of confidence of each participant. The relationships between postoperative advice, splint wear and wrist stiffness should be investigated in future research.

We observed that activity performance appeared to positively influence wrist movement through habituation. Habituation, a form of neuroplasticity, is a decreasing response to a repeated benign stimulus, whereby people can progressively filter out attention to irrelevant stimuli [36,37]. In our study, this appeared to occur through repetition. Participants frequently experienced initial movement as unpleasant, but repetition of a task or activity resulted in a reduction of unpleasant sensations and a normalisation of wrist movement. Habituation through occupation may work similarly to graded exposure where the incremental introduction of noxious stimuli reduces hypersensitivity or pain response [35,38]. Other actions of occupation may be through diversion from pain [8,39] or the greater efficiency of functional task performance versus exercise routines in promoting motor learning [40–42]. Educating patients that repetition of activity will lead to normalised wrist movement may help patients overcome the hurdle of initially unpleasant movement.

Our study also elucidated the scope of occupation in promoting recovery beyond that of inducing movement. There were psychological and social mechanisms at work. Fisher [43] discusses how engagement in occupation can have simultaneous actions of experiencing pleasure, productivity, and restoration, a finding supported by our study. Our participants experienced the restorative effect of joint movement through doing, while also feeling productive, optimistic and a welcomed sense of normality when doing. The desire to return to valued occupations acted as a strong driver during early rehabilitation constantly propelling people forward toward greater use of the affected wrist.

Occupation and exercise as synergistic interventions

Occupation as a therapy may be underutilised as a therapeutic strategy in early surgical distal radius fracture rehabilitation. Currently, the predominant approach tends to endorse exercise, but constrain activity during the first six weeks [1,6]. We propose that occupation and exercise be advocated as synergistically safe and beneficial during the early weeks of recovery. It is suggested that such an approach would be empowering for patients, fostering earlier independence and wellbeing [44], and facilitate wrist movement beyond the scope of exercise routines.

Viewing activity performance as a means rather than merely an end goal [45], is likely to represent a reversal in the way daily activities are perceived by many therapists and indeed, patients.

Rather than solely perceiving daily activities as something patients do once they have regained sufficient capacity, purposeful activities can be seen as a remediator of movement. In order to make such a shift, occupationally positive language that advocates safe and beneficial performance of daily activities would need to be adopted.

Through a practical lens, performance of daily activities could be included in home programmes, framed as a structured part of rehabilitation. Patients could be educated on intentionally performing tasks and activities that will provide a "just-right" [45,46] level of challenge. Education should highlight how daily activities also promote automatic movement through being ready-to-hand. Activity grading and self-regulation of activity performance could be taught in order to ensure that activities are commensurate with the stage of healing [47].

In addition, clinicians could promote the use of psychosocial strategies that participants used in this study such as optimism or problem-solving skills. Other strategies were focussing on the "can dos" rather than the "can't dos", using resilience gained from previous experiences, determination, positivity, and wellbeing practices. Engaging in activities and occupations was also reported as improving mood and wellbeing. This finding links strongly with the principles of positive psychology, where the building of capabilities rather than a direct alleviation of anxiety or negative cognitions is the focus of treatment [48,49]. Therapists could incorporate positive psychology strategies by helping patients to identify and harness psychosocial resources that enhance recovery.

Strengths and limitations

A key strength of this study is that participants were interviewed early after surgery, while still immersed in the recovery journey. A unique perspective situated in the social and health care context of Aoteaora, New Zealand was gained. The study brings a cross-disciplinary lens, propelling occupational and physio-therapists toward a greater understanding of the complimentary role of occupation and exercise. The study analysed narratives of 21 diverse participants but may not represent experiences of people from different social, cultural, or rehabilitation settings. Participants were not offered the opportunity to check the transcripts so the interview narratives must stand in their own right. Only one author conducted coding and initial theme development which may have resulted in a narrow interpretation of the data. This was mitigated by reflexive data analysis and regular author collaboration.

Conclusions

The study explored the ways that activities and occupations influenced recovery from surgical treatment of distal radius fractures. Participants highly valued daily activities for promoting recovery in the first eight weeks after surgery. Activities and occupations were found, subjectively, to be a strong driver of the rehabilitation process, positively influencing recovery through promoting wellbeing, wrist movement, and habituation. The study challenges therapists to use activities and occupation as a rich source of movement that can be exploited for therapeutic advantage. A postoperative approach that promotes occupation and exercise as synergistic interventions has the potential to result in improved outcomes and an holistic rehabilitation firmly centred on the individual. Future research that evaluates wrist movement during purposeful activities is planned. Data from the current and future studies can inform development of occupation-based interventions.

Acknowledgements

A professional transcriber was employed to transcribe the audio recordings.

Disclosure statement

The authors report no conflicts of interest.

Funding

The work was supported by research grants received from Counties Manukau Health, Hand Therapy New Zealand – Ringaromi Aoteaora and Occupational Therapy New Zealand – Whakaora Ngangahau Aotearoa.

ORCID

Julie M. Collis http://orcid.org/0000-0002-6560-6287
Elizabeth C. Mayland http://orcid.org/0000-0002-7887-1071
Valerie Wright-St Clair http://orcid.org/0000-0002-7505-3946
Nada Signal http://orcid.org/0000-0001-9595-0532

References

[1] Quadlbauer S, Pezzei C, Jurkowitsch J, et al. Rehabilitation after distal radius fractures: is there a need for immobilization and physiotherapy? Arch Orthop Trauma Surg. 2020;140:651–663.
[2] Egol KA, Karia R, Zingman A, et al. Hand stiffness following distal radius fractures. Bull Hosp Jt Dis. 2014;72:288–293.
[3] Karagiannopoulos C, Sitler M, Michlovitz S, et al. A descriptive study on wrist and hand sensorimotor impairment and function following distal radius fracture intervention. J Hand Ther. 2013;26(3):204–215.
[4] Chung KC, Haas A. Relationship between patient satisfaction and objective functional outcome after surgical treatment for distal radius fractures. J Hand Ther. 2009;22:302–308.
[5] Michlovitz SL, Festa L. Therapist's management of distal radius fractures. In: Skirven TM, Osterman AL, Fedorczyk J, editors. Rehabilitation of the hand and upper extremity. 6th ed. Philadelphia: Mosby; 2011. p. 949–962.
[6] Collis JM, Signal N, Mayland E, et al. A systematic review of how daily activities and exercises are recommended following volar plating of distal radius fractures and the efficacy and safety of early versus late mobilisation. Hand Ther. 2020;25(4):139–151.
[7] Daud AZC, Judd J, Yau M, et al. Barriers of occupation-based intervention. Asian J Qual Life. 2016;1(4):1–10.
[8] Colaianni D, Provident I. The benefits of and challenges to the use of occupation in hand therapy. Occup Ther Health Care. 2010;24:130–146.
[9] Amini DA, Kannenberg K, Bodison S, et al. Occupational therapy practice framework: domain & process 3rd edition. Am J Occup Ther. 2014;68:S1–S48.
[10] Polatajko HJ, Davis JA, Hobson SJ, et al. Meeting the responsibility that comes with the privilege: introducing a taxonomic code for understanding occupation. Can J Occup Ther. 2004;71:261–264.
[11] Collis JM, Signal N, Mayland E, et al. Influence of purposeful activities on upper extremity motor performance: a systematic review. OTJR. 2020;40:223–234.

[12] Craig P, Dieppe P, Macintyre S, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. Int J Nurs Stud. 2013;50:587–592.
[13] Thorne S. Interpretive description. 2nd ed. New York: Routledge; 2016.
[14] O'Brien BC, Harris IB, Beckman TJ, et al. Standards for reporting qualitative research: a synthesis of recommendations. Acad Med. 2014;89:1245–1251.
[15] Teodoro IPP, Rebouças VCF, Thorne SE, et al. Interpretive description: a viable methodological approach for nursing research. Esc Anna Nery. 2018;22(3):1–8.
[16] Hunt MR. Strengths and challenges in the use of interpretive description: reflections arising from a study of the moral experience of health professionals in humanitarian work. Qual Health Res. 2009;19:1284–1292.
[17] Fletcher AJ. Applying critical realism in qualitative research: methodology meets method. Int J Soc Res Methodol. 2017;20(2):181–194.
[18] Yucel R. Scientists' ontological and epistemological views about science from the perspective of critical realism. Sci Educ. 2018;27(5–6):407–433.
[19] Nairn S. A critical realist approach to knowledge: implications for evidence-based practice in and beyond nursing. Nurs Inq. 2012;19:6–17.
[20] Malterud K, Siersma VD, Guassora AD. Sample size in qualitative interview studies: guided by information power. Qual Health Res. 2016;26(13):1753–1760.
[21] MacDermid JC. Development of a scale for patient rating of wrist pain and disability. J Hand Ther. 1996;9:178–183.
[22] Woby SR, Roach NK, Urmston M, et al. Psychometric properties of the TSK-11: a shortened version of the Tampa Scale for Kinesiophobia. Pain. 2005;117:137–144.
[23] Larsson C, Hansson EE, Sundquist K, et al. Kinesiophobia and its relation to pain characteristics and cognitive affective variables in older adults with chronic pain. BMC Geriatr. 2016;16:128.
[24] Javed S, Shahid R, Thimmiah R, et al. Volar locking plate osteosynthesis for distal radial fractures. J Orthop Surg (Hong Kong). 2015;23(3):323–326.
[25] Eakman A, Carlson M, Clark F. The meaningful activity participation assessment: a measure of engagement in personally valued activities. Int J Aging Hum Dev. 2010;70:299–317.
[26] Poulsen HS, Hansen AØ. Occupational performance problems identified by 507 patients: an insight that can guide occupation-based hand therapy. Hand Ther. 2018;23(4):121–129.
[27] Wright-St Clair VA, Kepa M, Hoenle S, et al. Doing what's important: valued activities for older New Zealand Māori and non-Māori. Australas J Ageing. 2012;31:241–246.
[28] Manzano A. The craft of interviewing in realist evaluation. Evaluation. 2016;22(3):342–360.
[29] Thorne S. Entering the field. Interpretive description. London (UK): Routledge; 2016.
[30] Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol. 2006;3(2):77–101.
[31] Terry G, Hayfield N, Clarke V, et al. Thematic analysis. In: Willig C, Rogers WS, editors. The Sage handbook of qualitative research in psychology. London: SAGE Publications Ltd; 2017. p. 17–37.
[32] Mehta S, MacDermid JC, Tremblay M. The implications of chronic pain models for rehabilitation of distal radius fracture. Hand Ther. 2011;16(1):2–11.
[33] Björk M, Niklasson J, Westerdahl E, et al. Self-efficacy corresponds to wrist function after combined plating of distal radius fractures. J Hand Ther. 2020;33:314–319.
[34] Dewan N, MacDermid JC, Packham T. Role of a self-efficacy-based model of intervention: the LEARN approach in rehabilitation of distal radius fracture. Crit Rev Phys Rehabil Med. 2013;25(3–4):241–259.
[35] Hamasaki T, Pelletier R, Bourbonnais D, et al. Pain-related psychological issues in hand therapy. J Hand Ther. 2018;31(2):215–226.
[36] Siengsukon CF. Neuroplasticity. In: Lundy-Ekman L, editor. Neuroscience: fundamentals for rehabilitation. Philadelphia: Elsevier; 2012. p. 66–80.
[37] Podoly TY, Sasson AB. When it's impossible to ignore: development and validation of the Sensory Habituation Questionnaire. Am J Occup Ther. 2020;74:7403205040p1–7403205040p10.
[38] den Hollander M, Goossens M, de Jong J, et al. Expose or protect? A randomized controlled trial of exposure in vivo vs pain-contingent treatment as usual in patients with complex regional pain syndrome type 1. Pain. 2016;157(10):2318–2329.
[39] Nelson DL, Cipriani DJ, Thomas JJ. Physical therapy and occupational therapy: partners in rehabilitation for persons with movement impairments. Occup Ther Health Care. 2002;15:35–57.
[40] Boudreau SA, Farina D, Falla D. The role of motor learning and neuroplasticity in designing rehabilitation approaches for musculoskeletal pain disorders. Man Ther. 2010;15:410–414.
[41] Westlake KP, Byl NN. Neural plasticity and implications for hand rehabilitation after neurological insult. J Hand Ther. 2013;26:87–93.
[42] Valdes K, Naughton N, Algar L. Sensorimotor interventions and assessments for the hand and wrist: a scoping review. J Hand Ther. 2014;27:272–286.
[43] Fisher AG. Occupation-centred, occupation-based, occupation-focused: same, same or different? Scand J Occup Ther. 2014;21(Suppl. 1):96–107.
[44] Robinson LS, Brown T, O'Brien L. Embracing an occupational perspective: occupation-based interventions in hand therapy practice. Aust Occup Ther J. 2016;63(4):293–296.
[45] Gray JM. Putting occupation into practice: occupation as ends, occupation as means. Am J Occup Ther. 1998;52:354–364.
[46] Price P, Miner S. Occupation emerges in the process of therapy. Am J Occup Ther. 2007;61:441–450.
[47] Perlman C, Bergthorson M. Task, activity and occupational analysis. In: Curtin M, Egan M, Adams J, editors. Occupational therapy for people experiencing illness, injury or impairment. 7th ed. Edinburgh: Elsevier; 2017.
[48] Müller R, Gertz KJ, Molton IR, et al. Effects of a tailored positive psychology intervention on well-being and pain in individuals with chronic pain and a physical disability. Clin J Pain. 2016;32(1):32–44.
[49] Carr A, Cullen K, Keeney C, et al. Effectiveness of positive psychology interventions: a systematic review and meta-analysis. J Posit Psychol. 2020;1–21.

Appendix R: Study III summary of results for participants

Ngā mihi nui

Thank you for taking part in my study about your wrist fracture

The study was called 'Patient perspectives on recovery of wrist motion after surgery for distal radius fracture'

What was the study about?

The study was to find out how people use their wrist after surgery during day-to-day activities and occupations

I explored whether performing day-to-day activities had an influence on the recovery of wrist movement and use

Each story was so interesting and different. I enjoyed interviewing every participant and appreciated your willingness to take part

- I interviewed 21 people
- 14 were women and 7 were men
- Ages ranged from 28 to 74
- There was a broad range of different cultures and ethnicities
- I listened to the audio recordings, read the transcripts and reviewed the activity and exercise log
- I looked for experiences and thoughts that were similar between participants and experiences that were different

Results of the study

The study showed that doing day-to-day activities after surgery was a valued way of recovering movement and function in the operated wrist

I developed five 'themes' to describe how everyday activities helped with the recovery from surgery

I have summarized the themes on the next two pages and put in some quotes to illustrate each theme

The names used in the quotes are pseudonyms

Theme one: Occupation was a driving force of recovery

I just want life to go back to how it was. To be able to take the boat out and go fishing and ride my bike and stuff like that. Graeme, 46

- People said the injury was an unwanted disruption and many found life hard and frustrating
- There was a strong drive to get back to normal life
- People usually felt better and more optimistic once they started using their affected wrist

Theme two: occupation offered ready-to-hand challenges

I thought well, I just have to work it out. There's nobody else here to do it for you. If you don't do it, well you don't get any taties. Silky, 71

Day-to-day activities encouraged wrist movement because people had things they needed and wanted to do

- Some wrist movement happened automatically during daily activities
- Daily activities offered opportunity for light, easy wrist movement at the beginning that could be made harder as time went on

Theme three: occupation invited intentional doing

I want to get back to automatically using my right hand without thinking. And I think that to do it consciously, first of all, is the first step in doing that. Marie 71

- Participants said they had to make an effort to use their operated wrist. It didn't always happen naturally.
- Many people looked for opportunities to make themselves use their wrist
- Decisions on what activities to do were based on things like pain, common sense, or "trying it out", "testing my wrist"

Theme four: occupation habituated the wrist to movement

the more I do, the more I can do. Alexa, 36

Habituation means that repeating a task or activity got the wrist 'used to' movement

- Movement was often described as weird, robotic, or abnormal at the beginning
- Movement sometimes made people feel anxious or worried
- People noticed that persevering with an activity made movement feel more normal. It also built confidence in using the wrist

Initially when I'm doing a task it's a bit painful…like if I brush my teeth or apply moisturiser, the resistance was there, but if I …overcame it with tolerating a bit of pain…and pushing myself a bit, next time the wrist was used to the situation and it was better than before. Not so hard. Santosh, 30

Theme five: Re-engaging in everyday life required internal strength & strategies

I think it's a journey two ways. I think you've got a physical one and you've got a mental one. And…if the mental one's not on board then you're not going forward either.
Zoe, 68

- People in the study used mental focus and drew on strengths like perseverance, optimism or a strong belief in their ability to recover
- Many people used strategies like meditation, creativity, focusing on the positive, problem solving, acceptance or gratefulness
- These strengths helped people overcome the tough times during rehabilitation and helped them to 'get on' with life

I think the recovery of my wrist is a lot to do with the attitude of stubbornness and pig-headedness.
Bill, 72

What happens next?

The study gives new information about how everyday 'doing' helps recovery

The results from the study will be used to develop new approaches to rehabilitation.

Hand therapists can give better guidance on what activities people can do, how patients can use their wrist after surgery and what the benefits of active use are.

Hand therapists will be able to advise on using daily activities as well as exercises to help improve movement and strength

Your story will help develop new approaches to rehabilitation

I will be writing an article for a rehabilitation journal. If you would like a copy of this when it is published please let me know and I will send that to you

But yeah in terms of recovery, I'm just very blown away by how well I've come along and yeah I certainly do believe that that bit extra that I've been doing with my wrist, changing nappies and chopping things and a little bit of gardening and that, I definitely think it's helped to get me where I'm at now with that movement. May, 32

Thankyou once again for participating

Julie Collis
Julie.collis@aut.ac.nz

The study received ethics was approved by the Auckland University of Technology Ethics Committee on 30/07/2019, AUTEC Reference number: 19/224

Appendix S: Study IV Health and Disability Ethics Committees approval letter

Health and Disability Ethics Committees

Health and Disability Ethics Committees
Ministry of Health
133 Molesworth Street
PO Box 5013
Wellington
6011

0800 4 ETHICS
hdecs@health.govt.nz

18 May 2020

Mrs Julie Collis
School of Clinical Sciences
AUT University North Campus
90 Akoranga Drive
Northcote
Auckland 0627

Dear Mrs Collis

Re:	**Ethics ref:**	**20/NTA/28**
	Study title:	An evaluation of wrist movement during purposeful activities and wrist exercises after surgery for distal radius fracture: A randomised crossover trial

I am pleased to advise that this application has been *approved* by the Northern A Health and Disability Ethics Committee. This decision was made through the HDEC-Full Review pathway.

Conditions of HDEC approval

HDEC approval for this study is subject to the following conditions being met prior to the commencement of the study in New Zealand. It is your responsibility, and that of the study's sponsor, to ensure that these conditions are met. No further review by the Northern A Health and Disability Ethics Committee is required.

Standard conditions:

1. Before the study commences at *any* locality in New Zealand, all relevant regulatory approvals must be obtained.
2. Before the study commences at *any* locality in New Zealand, it must be registered in a clinical trials registry. This should be a WHO-approved registry (such as the Australia New Zealand Clinical Trials Registry, www.anzctr.org.au) or https://clinicaltrials.gov/.
3. Before the study commences at *each given* locality in New Zealand, it must be authorised by that locality in Online Forms. Locality authorisation confirms that the locality is suitable for the safe and effective conduct of the study, and that local research governance issues have been addressed.

After HDEC review

Please refer to the *Standard Operating Procedures for Health and Disability Ethics Committees* (available on www.ethics.health.govt.nz) for HDEC requirements relating to amendments and other post-approval processes.

Your next progress report is due by 17 May 2021.

Participant access to ACC

The Northern A Health and Disability Ethics Committee is satisfied that your study is not a clinical trial that is to be conducted principally for the benefit of the manufacturer or distributor of the medicine or item being trialled. Participants injured as a result of treatment received as part of your study may therefore be eligible for publicly-funded compensation through the Accident Compensation Corporation (ACC).

Please don't hesitate to contact the HDEC secretariat for further information. We wish you all the best for your study.

Yours sincerely,

Kate O'Connor
Acting Chairperson
Northern A Health and Disability Ethics Committee

Encl: appendix A: documents submitted
appendix B: statement of compliance and list of members

Appendix T: Study IV localities approval letter

COUNTIES MANUKAU HEALTH

Research & Evaluation Office
Level 1, Ko Awatea, Middlemore Hospital
100 Hospital Road, Otahuhu; Private Bag 93311, Auckland – 1640
cmdhb.org.nz – koawatea.co.nz

18 June 2020

For the attention of: Julie Collis

Thank you for the information you have supplied to the CM Health Research & Evaluation Office regarding the following research proposal:

CM Health Research Registration Number: 1221
Ethics Approval Reference Number: HDEC: 20/NTA/28
Research Project Title: Evaluation of wrist movement during purposeful activities and wrist exercises after surgery for distal radius fracture

I am pleased to inform you that the CM Health Research Office has received all the required service lead approvals and the Chief Medical Officer's final sign-off for the above research project, which has you named as the Principal Investigator.

This CM Health locality approval is valid until 31 March 2022, which is the Final Reporting Date specified on your registration information.

All external reporting requirements must be adhered to. Please note that failure to notify us of amendments, and/or submit copies of annual Progress Reports and annual Ethics renewal letters may result in the withdrawal of ethical and CM Health organisational approval.

FINAL REPORT: It is a requirement of the CM Health Research Policy that all research and audit projects conducted within CM Health should complete the CM Health Final Report template and submit no later than 3 months following completion of the study. This report is to be uploaded to your study file on the Registry and is viewable by CM Health staff. Contact us for the report template or download it from the Registry.

Yours sincerely

A Bennett.

Angela Bennett
Research Coordinator
Counties Manukau Health
Under delegated authority from CM Health Research Committee and the Chief Medical Officer

Appendix U: Study IV purposeful activity criteria and suggestions

Purposeful Activity

Please choose an everyday activity that
1. challenges you to move your operated wrist
2. requires repeated movement of the wrist and forearm
3. is important to you or enjoyed by you
4. will take at least 10 minutes to perform

The activity can be adapted to be suitable for your operated wrist. For example, you might only use your operated wrist for some parts of the activity, or you might make the activity easier than it would normally be. The point is to choose something that will encourage movement in your wrist.

For the next session, you will need to have all the materials you need to perform the activity ready. You can ask someone else to have this ready for you.

Examples of activities

Preparing and consuming a hot drink

Cooking activity e.g. chopping up vegetables, making a salad, making roti, baking

Preparing a light meal or snack

Cleaning activity e.g. tidying, cleaning kitchen, dusting, cleaning equipment, polishing shoes

Drying the dishes, filling/emptying the dishwasher

Laundry e.g. folding and putting away laundry or hanging out laundry on a clothes horse/washing line

Unpacking groceries

Bed making

Dressing: putting on clothing, doing up shoelaces, buttons, tying scarf, tie

Art activity e.g. painting

Handcraft activity e.g. origami, needlework, scrapbooking, sewing

Workshop activity e.g. electronics, woodwork, car maintenance

Repairing activity e.g. repairing an appliance, electronic device

Pet care activity: grooming, stroking, feeding, playing

Music activity e.g. playing a musical instrument

Wrapping gifts

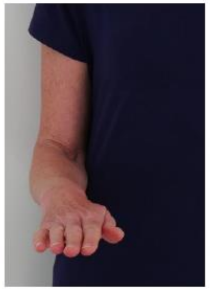
Indoor plants care e.g. watering plants, trimming leaves

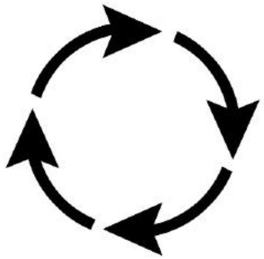
Gardening activity e.g. pulling weeds, light pruning

Playing a game e.g. cards, jigsaw, video game

You can combine activities if you want to

Appendix V: Study IV ROM exercises and instructions

Range of Movement Exercises	
For each exercise do 10 repetitions. Do them in the order given.	
Wrist flexion and extension With your arm resting on a table 1. Bend your wrist down so your hand is pointing down, hold for 3 seconds 2. Bend your wrist up so your hand is pointing up, hold for 3 seconds	 
Wrist radial and ulnar deviation With your arm resting on a table 1. Bend your hand up towards your thumb, hold for 3 seconds 2. Bend your hand down towards your little finger, hold for 3 seconds	 
Forearm supination and pronation With your elbow at your side 1. Turn your hand to face upwards, hold for 3 seconds 2. Turn your hand to face downwards, hold for 3 seconds	 

Thumb 1. Bend your thumb across your hand towards your little finger, hold for 3 seconds 2. Stretch your thumb away from your hand, hold for 3 seconds 3. Touch thumb to tip of each finger	  
Fingers With your arm resting on a table 1. Bend your fingers to make a fist, hold for 3 seconds 2. Open your fingers out straight, hold for 3 seconds	 
Circumduction Touch your thumb and index fingertip together lightly, make a circle	 

1. Krischak GD, Krasteva A, Schneider F, et al. Physiotherapy after volar plating of wrist fractures is effective using a home exercise program. *Arch Phys Med Rehabil* 2009; 90: 537-544.
2. Quadlbauer S, Pezzei C, Jurkowitsch J, et al. Rehabilitation after distal radius fractures: is there a need for immobilization and physiotherapy? *Arch Orthop Trauma Surg* 2020; 140: 651-663.
3. Watson N, Haines T, Tran P, et al. A Comparison of the Effect of One, Three, or Six Weeks of Immobilization on Function and Pain After Open Reduction and Internal Fixation of Distal Radial Fractures in Adults: A Randomized Controlled Trial. *J Bone Joint Surg* 2018; 100: 1118-1125.

Appendix W: Study IV flyer

Your treatment and therapy will be exactly the same whether you take part in this study or not

What are my rights?

- Taking part in this study is completely voluntary
- Your participation will not change the treatment you receive for your injury
- You can choose to leave the study at any time if you do not want to continue
- You will receive a $40.00 koha/gift as a thankyou

AUT

AUT CENTRE FOR ACTIVE AGEING

Who is running the study?

- The study is being run by Julie Collis as part of a PhD qualification at Auckland University of Technology
- The study received ethics approval from the Health and Disability Ethics Committee on: 18/05/2020
- Reference number: 20/NTA/28
- Julie is an occupational therapist/hand therapist who works for Counties Manukau at Hand Therapy, Manukau Super Clinic

What can I do next?

If you would like to know more

- Fill in the 'Expression of Interest Form' and give to your therapist
- Email, call or text Julie Collis

julie.collis@aut.ac.nz

021510083

Nga mihi nui,
thank you for reading this brochure

Tēnā koe

You are invited to take part in a study about wrist movement after surgery

What is the study about?

The study is called:

Evaluation of wrist movement after surgery for distal radius fracture

It is to find out how you move your wrist when you are doing exercises or everyday activities

We want to learn more about how to help patients recover wrist movement after surgery

Why are we doing the study?

Hand therapists use different treatments to help patients recover movement. We want to learn about different ways to do this

The study will help us understand more about the type of movement that happens when you do exercises and when you do everyday activities

What will I have to do?

You are asked to do two things:

1. Attend a one hour visit from the researcher to answer some questions and have the study explained
2. Attend a two to three hour visit to measure your wrist while doing an activity and wrist exercises

Both visits will be at your home

At the second visit I will put electronic measuring devices on your wrist

You will then:

i. perform a set of usual wrist exercises or an everyday activity for 10-minutes
ii. Rest for 60-minutes
iii. perform a set of usual wrist exercises or an activity for 10-minutes

Your hand and wrist movements will be video recorded while you are doing the activity and the exercises

The devices look like this and will measure your wrist while it is moving:

The devices are wireless and send the information to a computer

The devices are safe and will not harm you in any way

What happens with my information?

You will be asked for written consent

Data from the study will be analysed using statistical analysis

Results will be used for writing a thesis and a journal article

Video images will be destroyed at the end of the study

Participant Information Sheet

Study title:

Evaluation of wrist movement after surgery for distal radius fracture (broken wrist)

Ethics committee ref.: Approved by the Health and Disability Ethics Committee, 18/05/2020. Reference number, 20/NTA/28

Locality: AUT University

Lead investigator: Julie Collis **Contact phone number: 021510083**

Tēnā koe. Ko Julie Collis toku ingoa. You are invited to take part in a study on wrist movement during exercises and daily activities after surgery for a distal radius fracture (broken wrist). Whether or not you take part is your choice. If you don't want to take part, you don't have to give a reason, and it won't affect the care you receive. If you do want to take part now, but change your mind later, you can pull out of the study at any time.

This Participant Information Sheet will help you decide if you'd like to take part. It sets out why we are doing the study, what your participation would involve, what the benefits and risks to you might be, and what would happen after the study ends. We will go through this information with you and answer any questions you may have. You do not have to decide today whether or not you will participate in this study. Before you decide you may want to talk about the study with other people, such as family, whānau, friends, or healthcare providers. Feel free to do this.

If you agree to take part in this study, you will be asked to sign the Consent Form on the last page of this document. You will be given a copy of both the Participant Information Sheet and the Consent Form to keep.

This document is 7 pages long, including the Consent Form. Please make sure you have read and understood all the pages.

What is the purpose of the study?

The aim of this study is to learn about the type of wrist movement that happens when you do wrist exercises and everyday activities. I am doing this research so that we can understand more about how exercises and everyday activities promote movement in your wrist after surgery.

The research is a biomechanical study. This means that we are finding out how the human body works to make movement happen in joints. In this study we are exploring the ways that movement happens in your wrist when you do an everyday activity or a set of wrist exercises.

The results of the research will be used in future research. We will be able to use the information to design therapies that include the use of everyday activities. After that we can do further research that will find out if activity-based therapies are helpful for people with your injury.

If you take part in this research, you will continue to attend hand therapy as usual. Your hand therapist will give you exercises to perform and advice about the kinds of daily activities that you can do. Exercises and activities are important and are known to help in your recovery and it is important that you carry on with these as advised by your hand therapist.

The study has received funding from Hand Therapy New Zealand and Counties Manukau District Health Board. These research grants provide funding for the equipment, travel costs of the researcher and participant reimbursement.

Julie Collis is an Occupational Therapist and a New Zealand registered Hand Therapist with more than twenty years of experience. Julie is doing this research as part of her PhD (Doctor of Philosophy). Julie also works at the Manukau Super Clinic Hand Therapy Clinic and teaches hand therapy at the Auckland University of Technology.

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details: Julie Collis, Julie.collis@aut.ac.nz, 021510083

Project Supervisor Contact Details: Dr Valerie Wright St-Clair, valerie.wright-stclair@aut.ac.nz, +64 9 921 9999 ext 7736

What will my participation in the study involve?

You are being asked to participate because you had surgery for your broken wrist in the past four weeks. I am asking people over the age of 18. I am not asking people who have had other injuries to their hands or wrists at the same time or people who do not have normal use of their operated hand because of a stroke or severe arthritis.

If you take part in this research, you will continue to attend hand therapy as usual. There will be no changes to your usual hand therapy.

If you agree to take part, you will be asked to:

1. Attend a **60-minute visit** at your home or the hand therapy clinic. This will be at 3-5 weeks after your operation. I will ask you to sign a consent form to say you understand what is involved in the research. You will be asked to fill out some forms about yourself (age, gender, ethnicity, how you injured your wrist). I will explain the study, show you the wrist exercises and ask you to choose an activity from a list. You will choose an everyday activity that is important to you and that is somewhat challenging (encourages you to move your wrist during the activity, but not too much). The activity will be one that is part of your usual rehabilitation program. I will show you the electronic device (electrogoniometer) and you will watch a short video that explains the device.
2. Take part in a **2-3 hour session** where you will have your wrist measured. This will be at 4-8 weeks after your operation. You will have an electronic device, called an electrogoniometer, fitted to your wrist and forearm This device will take measurements of your wrist such as range of movement, speed of movement, length of time your wrist is moving.

   You will perform ten minute sessions of;

   a. Range of movement exercises – these will be the same exercises you are already doing for your wrist
   b. An everyday activity such as preparing a snack, folding washing, taking care of houseplants, light cleaning or a game. You will choose the activity from a list that will be provided. The activity is one that you would be expected to do during your rehabilitation.

   You will be randomised to doing either the activity or exercises first. You will have a 60-minute rest period in between. The reason that you are randomised to the order of activity or exercise is so we can find out whether it makes a difference which order you do them in.

The movement of your hands and wrists will be video recorded during both sessions.

At the end of the two sessions you will be asked to complete questionnaires on your pain, if you were worried about moving your wrist and about the activity you chose (how important it is to you, how much you enjoyed it and how challenging it was).

After this session the study is completed and you will not be asked to do anything more.

The information I will be asking about you is: your name, address, contact details, age, gender, ethnicity, date of the injury and surgery, type of work that you do and any medical history that affects the use of your operated hand (e.g. a past stroke, wrist injury or severe arthritis). I will not be asking any sensitive or personal questions.

Your medical records will be accessed for this research. Only information about your injury will be accessed including x-rays, CT scans, your operation note and discharge report. This information is accessed for the purposes of confirming dates of injury and surgery, and the type of injury and surgery you had. Only the researchers Julie Collis, Valerie Wright-St Clair and Nada Signal will have access to this information.

What are the possible benefits and risks of this study?

This research should not be uncomfortable or risky for you. You are not being asked to do anything that is not part of usual rehabilitation after surgery for a distal radius fracture. You will not be asked to do anything that is painful or uncomfortable.

You will have an electrogoniometer fitted: one to your wrist and one to your forearm during session two. This is a lightweight device that fits on the back of your wrist (see picture below). It will be attached by medical tape. The device is lightweight and allows your wrist to move freely. It is safe for people who have had surgery and metal implants. The device sends information to a computer via a wireless connection.

If you become uncomfortable or have pain during session two or do not like the feel of the electrogoniometer you can choose to withdraw from the study or you can choose to stop or have a rest. You do not have to continue if you do not wish to.

This study will help people who have a similar injury in the future. The information from this study is to explore about the types of movement that happen during activities and exercises. The information will be used to develop hand therapy interventions to help people with wrist surgery.

Who pays for the study?

There are no financial costs to you. The total cost in time will be three to four hours over two sessions:

Costs in time

1. A 60 minutes appointment, at three to five weeks after your operation
2. A two to three hour session at four to eight weeks after your operation

Both visits will be at your home or at your hand therapy clinic. The appointments can happen when you have other appointments at Manukau Super Clinic or your hand therapy clinic.

A gift voucher of $40 will be given to all participants.

What if something goes wrong?

If you were injured in this study, you would be eligible **to apply** for compensation from ACC just as you would be if you were injured in an accident at work or at home. This does not mean that your claim will automatically be accepted. You will have to lodge a claim with ACC, which may take some time to assess. If your claim is accepted, you will receive funding to assist in your recovery.

If you have private health or life insurance, you may wish to check with your insurer that taking part in this study won't affect your cover.

What are my rights?

It is your choice whether you take part in the study. Whether or not you take part is your choice. If you don't want to take part, you don't have to give a reason, and it won't affect the care you receive. If you do want to take part now, but change your mind later, you can pull out of the study at any time and it won't affect the care you receive.

You have the right to access the information collected about you as part of the study. You will be told of any new information about adverse or beneficial effects related to the study that becomes available during the study that may have an impact on your wrist injury.

All information that is collected will be kept private and confidential. Your data will be kept in a password protected computer. This research is completely separate from your hand therapy and I won't be talking to your therapist or surgeon and they won't be talking to me about the information from the study. The only people who will have access to your information are the researchers involved in this project – Julie Collis and my PhD supervisors Professor Valerie Wright St-Clair, Dr Nada Signal and Dr Elizabeth Mayland.

The findings will be written up in my PhD thesis and may be published in a conference paper or journal article. None of these publications will contain your name or have any other way of identifying you.

Privacy of your video data

The video data is being collected so that I can check your movements against the electronic data. The video will be set up so that as much as possible I will record only images of your hands and wrists and your face will not be filmed. It is possible that other images will be filmed such as your surroundings. You will be able to choose where the filming and measurements take place. You will be able to remove any items in the surrounding area such as photographs that you do not wish to be in the background. At the end of filming the images will be edited and as much as possible will be cropped to include only footage of your hands and wrists. The video data will not be shared with anyone other than the researchers Julie Collis, Valerie Wright-St Clair, Nada Signal and Elizabeth Mayland. The video images will not be used in any publication or other forum. All video data will be deleted after the data has been analysed.

What happens after the study or if I change my mind?

All data collected will be stored electronically and will be password protected. This data will be held for 10 years and then destroyed. The data will not be used in the future for any other purposes.

If you wish, I will send you a summary of the study results at the end of the project. You would expect to receive this by the end of 2021. If there is a journal article published as a result of this research a copy will be made available to you.

Who do I contact for more information or if I have concerns?

If you have any questions, concerns or complaints about the study at any stage, you can contact:

Professor Valerie Wright St-Clair (valerie.wright-stclair@aut.ac.nz, +64 9 921 9999 ext 7736).

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone:	0800 555 050
Fax:	0800 2 SUPPORT (0800 2787 7678)
Email:	advocacy@advocacy.org.nz
Website:	https://www.advocacy.org.nz/

For Maori health support please contact :

Name, position: Te Kaahui Ora Maaori Health Unit
Telephone number: 09 276 0138
Email: tekahuiora@middlemore.co.nz

You can also contact the health and disability ethics committee (HDEC) that approved this study on:

Phone:	0800 4 ETHICS
Email:	hdecs@moh.govt.nz

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Consent Form

Please tick to indicate you consent to the following:

I have read, or have had read to me in my first language, and I understand the Participant Information Sheet.		
I have been given sufficient time to consider whether or not to participate in this study.		
I have had the opportunity to use a legal representative, whanau/ family support or a friend to help me ask questions and understand the study.		
I am satisfied with the answers I have been given regarding the study and I have a copy of this consent form and information sheet.		
I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without this affecting my medical care.		
I agree to have my wrist measured by an electrogoniometer while doing wrist exercises and an activity		
I understand my wrist and hand movements will be video recorded during the study and that the videos will be deleted at the completion of data analysis		
I consent to the research staff collecting and processing my information, including information about my health.		
I consent to the research staff accessing my medical records about my injury and surgery. This may include x-rays, CT scans, my operation note and discharge report.		
If I decide to withdraw from the study, I agree that the information collected about me up to the point when I withdraw may continue to be processed.	Yes ☐	No ☐
I consent to my GP or current provider being informed about my participation in the study and of any significant abnormal results obtained during the study.	Yes ☐	No ☐
I agree to an approved auditor appointed by the New Zealand Health and Disability Ethic Committees, or any relevant regulatory authority or their approved representative reviewing my relevant medical records for the sole purpose of checking the accuracy of the information recorded for the study.		

I understand that my participation in this study is confidential and that no material, which could identify me personally, will be used in any reports on this study.		
I understand the compensation provisions in case of injury during the study.		
I know who to contact if I have any questions about the study in general.		
I understand my responsibilities as a study participant.		
I wish to receive a summary of the results from the study.	Yes ☐	No ☐

Declaration by participant:

I hereby consent to take part in this study.

Participant's name:

Signature: Date:

Declaration by member of research team:

I have given a verbal explanation of the research project to the participant, and have answered the participant's questions about it.

I believe that the participant understands the study and has given informed consent to participate.

Researcher's name:

Signature: Date:

Appendix Y: Study IV raw data graphs

Supplementary file four: Box and scatter graphs visualising the raw data for all movement outcomes

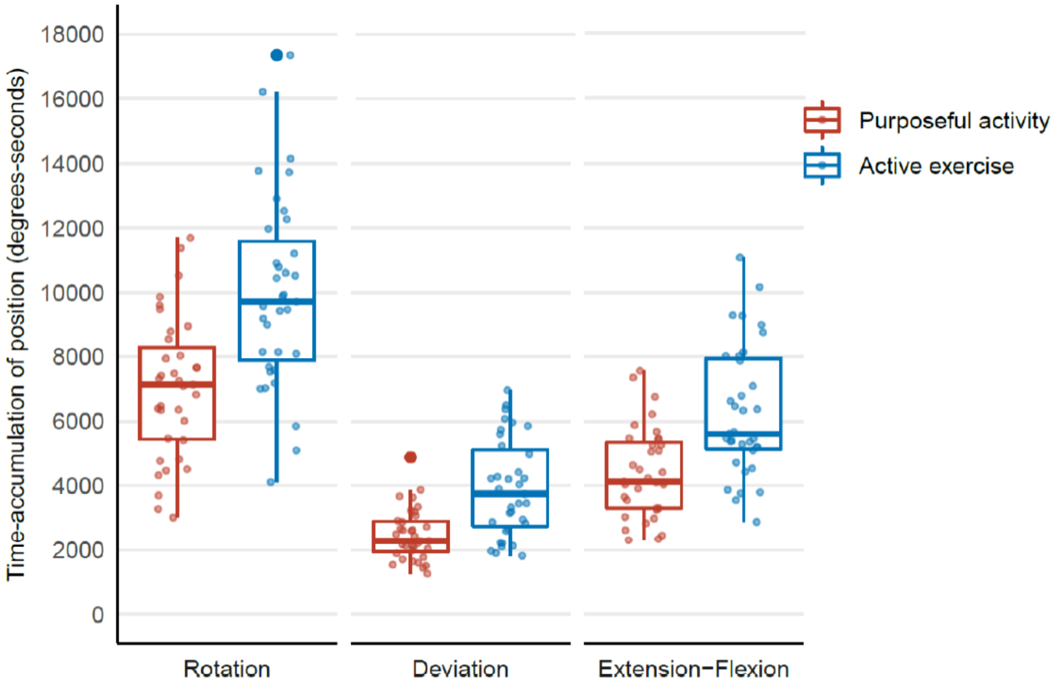


Figure 1. Visualisation of raw data for Time-Accumulation of joint Position (TAP) for all movement types. The box represents the median, 25th and 75th percentile, bars the range, and dots a single data-point

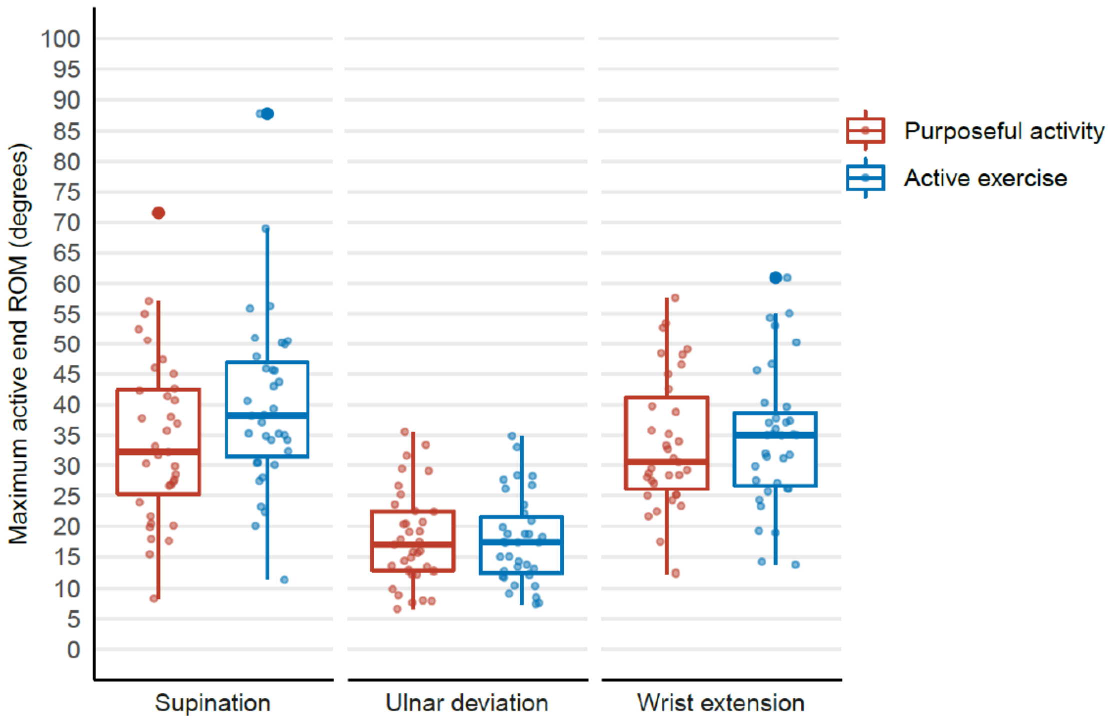


Figure 2. Visualisation of raw data for Maximum active End ROM (MaxER) for all movement types. The box represents the median, 25th and 75th percentile, bars the range, and dots a single data-point

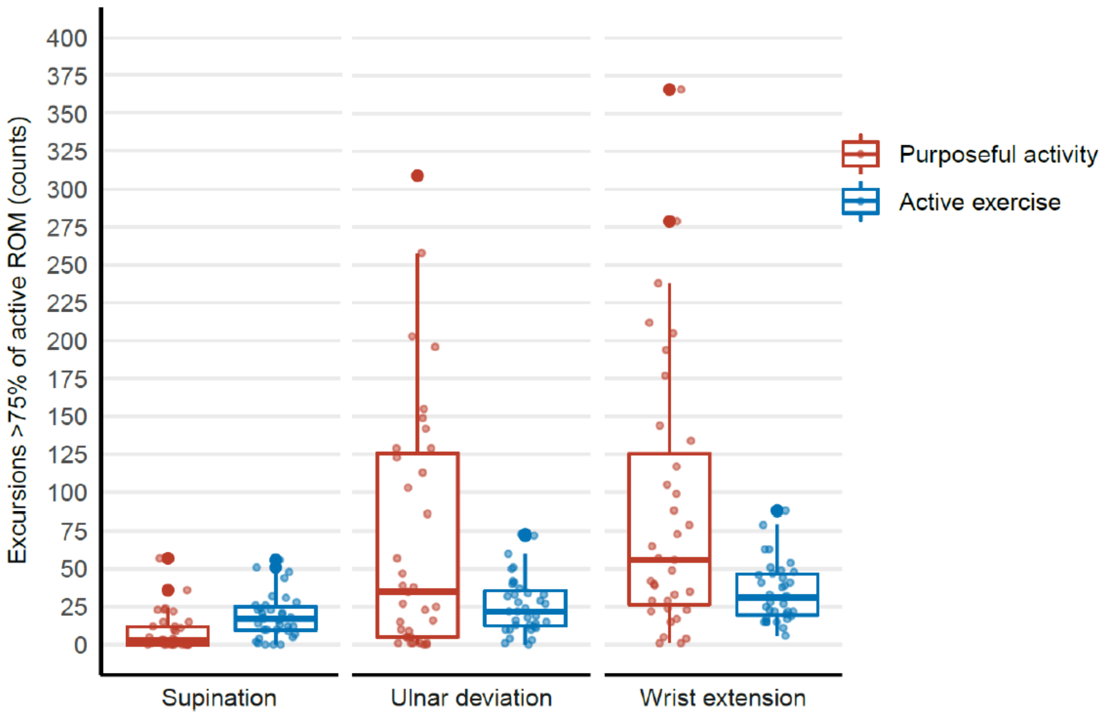


Figure 3. Visualisation of raw data for Excursions >75% of the available active ROM (E>75%) for all movement types. The box represents the median, 25th and 75th percentile, bars the range, and dots a single data-point

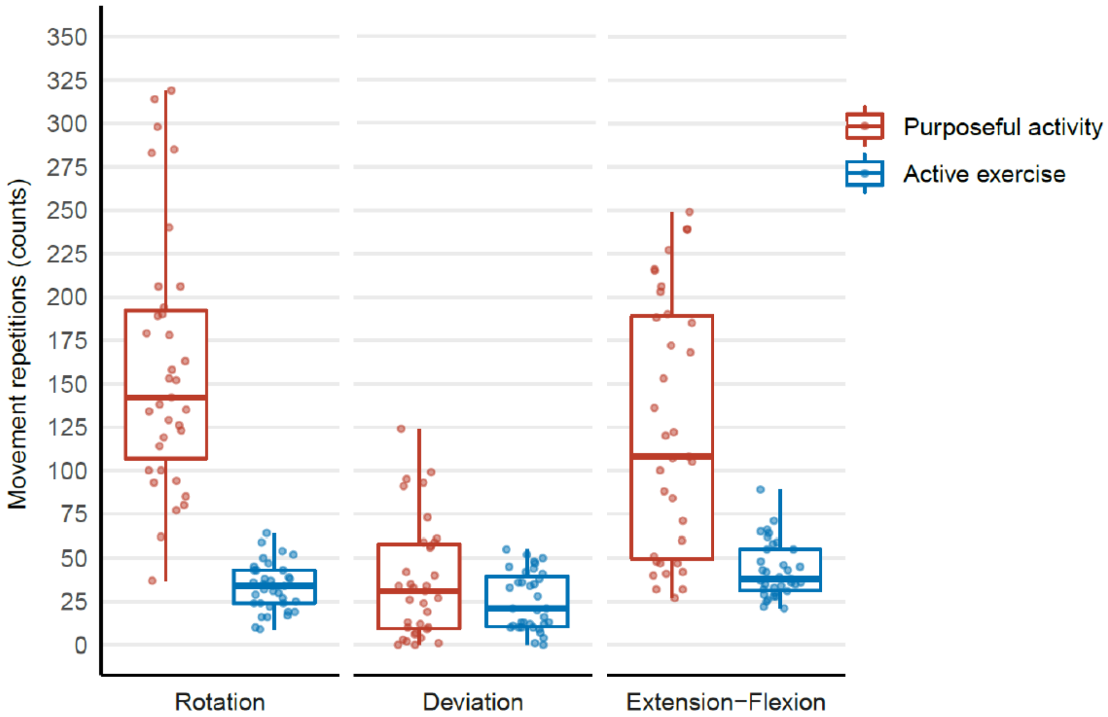


Figure 4. Visualisation of raw data for Movement Repetitions (MR) for all movement types. The box represents the median, 25th and 75th percentile, bars the range, and dots a single data-point

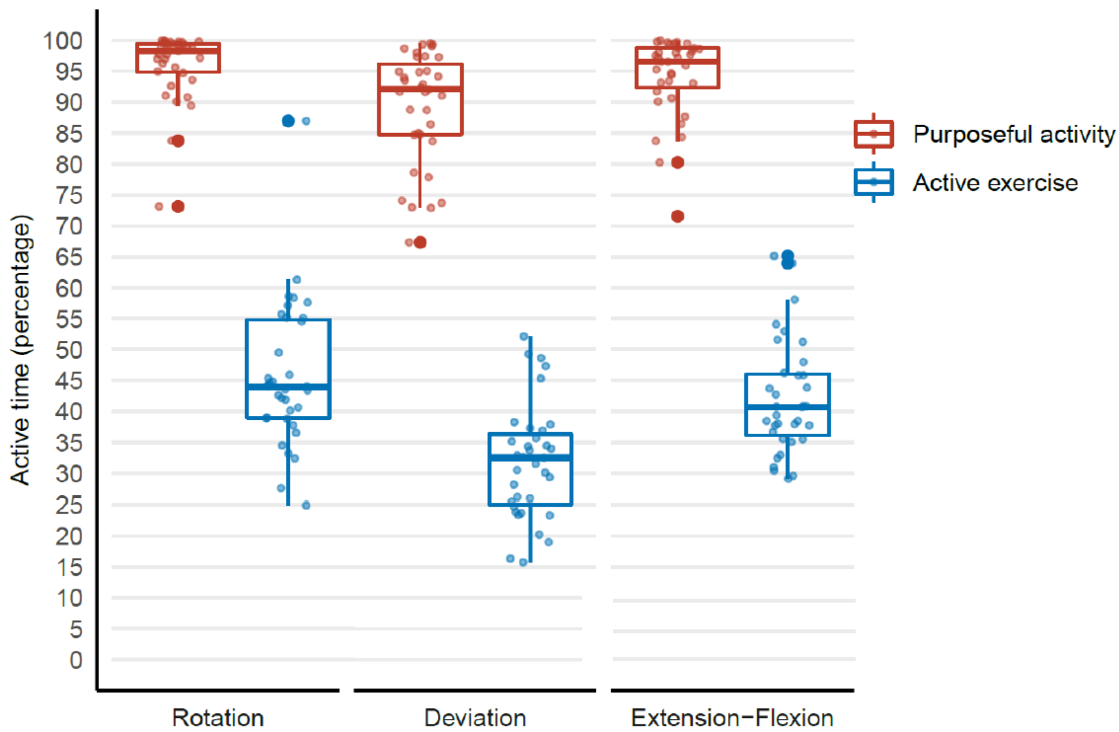


Figure 5. Visualisation of raw data for Active Time (AT) for all movement types. The box represents the median, 25th and 75th percentile, bars the range, and dots a single data-point

Appendix Z: Study IV summary for participants

Ngā mihi nui

Thank you for taking part in my study about movement in your wrist after a distal radius fracture

Summary of results

The study measured and compared wrist and forearm movement during everyday activities and exercises

Why was the study done?

At about 7 to 10 days after surgery people usually see a hand therapist. People are taught wrist exercises and given a wrist splint. The exercises are to help people get their movement back.

Everyday activities can also be used as 'exercise' or therapy to restore wrist movement i.e., moving the wrist when getting dressed, drying dishes or folding clothes.

Hand therapists do not usually teach people to use daily activities as part of their home therapy programme. One reason is because we don't know how much movement people get when they're doing everyday activities.

What was the purpose of the study?

The purpose of the study was to find out how much movement people get when they're doing everyday activities compared to doing exercises.

Results of the study?

Thirty-five people, aged between 19 and 76 years of age took part in the study

People chose a variety of activities: folding the washing, hanging clothes out, tidying, ironing, washing windows, doing dishes, preparing food or a cup of tea, gardening, putting on clothing, doing hair, self-care, sewing, drawing, or playing a musical instrument.

What did we learn from the study?

My study showed that movement during activities and exercises is different

Joint position and amount

During each exercise repetition the wrist moved more slowly to the maximum position and was held there for longer than during activities

Maximum movement

During activities, the wrist moved to the same maximum wrist position as during exercises.

Movement close to maximum

During everyday activities, the wrist moved close to the maximum position over twice as often as during exercises

Moving versus not moving

During daily activities, the wrist and forearm were moving almost 100% of the time compared with less than 50% of the time during exercises

Repetitions (times the wrist moved)

People performed 2-4 times more repetitions during daily activities, than during exercises

Key results

Activity produces as much maximum wrist movement as exercises, you get there more times, and your wrist is moving more of the time during activities

The results were exciting because they show that a lot more movement happens during everyday activities than we thought. This is important because people need to move their wrist a lot to restore movement.

The study showed that doing daily activities is a very good way to produce wrist movement after surgery for a distal radius fracture.

What happens next

The information from the study will be used to change the advice hand therapists give to people after surgery.

Because we now know more about movement during daily activities, we can show people how to use light activities to restore movement.

Thank you

I would like to say a very big thank you to everybody who took part in my study. I was so appreciative of your time and willingness to take part.

If you would like more information don't hesitate to get in touch with me

julie.collis@aut.ac.nz