Physiotherapy Treatment and Patient Outcomes Following Anterior Cruciate Ligament Reconstruction Surgery in New Zealand

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Abstract

An anterior cruciate ligament (ACL) rupture is a devastating injury that frequently occurs during sporting activities. Surgical reconstruction of the disrupted ligament, followed by extended rehabilitation, is often undertaken as a means to restore pre-injury functional ability. Rehabilitation, which typically includes physiotherapy treatment, can have a significant impact on patient outcomes following ACL reconstruction (ACLR) surgery; however, the relationship between treatment and outcome is not clear. Therefore, we undertook a series of four studies to determine the nature of the relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following primary ACLR in New Zealand (NZ).

In study one, physiotherapy treatment data from the Accident Compensation Corporation of NZ revealed NZ ACLR patients received between 8-12 physiotherapy treatments over 143-161 days following surgery. The absence of patient outcome data did not allow the relationship with physiotherapy treatment data to be determined.

Study two was a systematic review of previous literature, which showed no clear relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following primary ACLR could be established.

In study three, we used patient outcome data from the NZ ACL Registry and physiotherapy treatment data from ACC to show physiotherapy treatment in the first 12 months after ACLR increased the likelihood of achieving a patient acceptable symptom state on the Knee Injury and Osteoarthritis Outcome Score questionnaire. However, post-operative physiotherapy treatment did not increase the likelihood of achieving a normative Marx Activity Rating Scale score in the 24 months following ACLR. Also identified was that NZ ACLR patients received less than 12 physiotherapy treatments over an average of 185 days following surgery.

In study four, we surveyed NZ physiotherapists regarding their beliefs and practices on ACLR rehabilitation, in an attempt to understand possible reasons for the dosage of treatment patients receive following surgery. The dosage of physiotherapy treatment NZ physiotherapists believe they are providing is not consistent with the dosage of

treatment NZ ACLR patients are receiving, and the utilisation of patient-reported outcome measures and validated objective methods to assess patient outcomes by NZ physiotherapists following ACLR is low.

Although NZ ACLR patients received a low dosage of physiotherapy treatment following surgery, the absolute quantity of treatment does not appear to have a significant effect on patient outcomes, with other factors (patient age, gender, delay to ACLR) possibly having greater impacts. Physiotherapy treatment following ACLR can, however, increase a patients acceptance of any ongoing post-surgical symptoms and functional limitations. Multiple factors, including ACC policy and processes, likely influence the dosage of physiotherapy treatment received by NZ ACLR patients. Regular assessment of the patients status and function by the physiotherapist during ACLR rehabilitation may increase adherence to the rehabilitation programme, potentially increasing the dosage of treatment received and improving patient outcomes. NZ physiotherapists may need to increase their knowledge and skills regarding end-stage ACLR rehabilitation to effectively manage their patient throughout a return to pre-injury activities.

Table of Contents

List of Figures

List of Tables

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.

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Co-Authored Works Arising From This Thesis

Published Manuscripts

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3. Fausett, W., Reid, D., & Larmer, P., & Garrett, N. (2023). Patient acceptance of knee symptoms and function after anterior cruciate ligament reconstruction is improved by physiotherapy treatment. *New Zealand Journal of Physiotherapy, 51*(1), 53–69. doi:10.15619/NZJP/51.1.07 (Appendix C).
4. Fausett, W., Reid, D., & Larmer, P. (2022) Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport following anterior cruciate ligament reconstruction: A survey. *Physical Therapy in Sport*, *53*, 166-172. doi:10.1016/j.ptsp.2021.10.012 (Appendix D).

Peer-reviewed Conference Presentations

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Statement of Contribution

Chapter Two

Fausett, W., Wilkins, F., Reid, D., Larmer, P., & Potts, G. (2019). Physiotherapy treatment and rehabilitation following anterior cruciate ligament injury in New Zealand: Are we doing enough? *New Zealand Journal of Physiotherapy*, *47*(3), 139-149. doi:10.15619/NZJP/47.3.02	Fausett: 90% Wilkins: 2.5% Reid: 2.5% Larmer: 2.5% Potts: 2.5%

Chapter Three

Fausett, W., Reid, D., & Larmer, P. (2023). The relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following primary anterior cruciate ligament reconstruction: A systematic review. *Physical Therapy Reviews*, 28(2), 111-134, doi:10.1080/10833196.2023.2195213	Fausett: 90% Reid: 5% Larmer: 5%

Chapter Four

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Chapter Five

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We, the undersigned, hereby agree to the contribution percentages to the chapters identified above:

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Ethical Approval

Chapter Two

Ethical approval was sought retrospectively for this study. However, as advised by the Auckland University of Technology Ethics Committee (AUTEC), this study did not meet the threshold to require ethical approval as all data remained de-identified during collection and analysis.

Chapter Four

Ethical approval for this research was obtained from the Auckland University of Technology Ethics Committee (AUTEC); approval number 19/293. (Appendix E)

Chapter Five

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Chapter 1

Introduction

1.1 Anterior Cruciate Ligament Injury

As the anterior cruciate ligament (ACL) of the knee resists anterior tibial translation and rotational loads, it is a key stabiliser of the joint during dynamic activities that involve jumping, pivoting, and rapid changes of direction (Badawy et al., 2022; Duthon et al., 2006). Knee injuries commonly occur during sporting activities, with the ACL one of the most frequently injured structures in the knee (Majewski et al., 2006). Every year there are over two million ACL injuries worldwide (Renström, 2013), with an annual incidence rate between 0.01 and 0.05%, or 8-47 per 100,000 people (Moses et al., 2012). In a retrospective 20-year analysis of a United States (US) population, the annual incidence of ACL injury was reported as 68.6 per 100,000 person-years, with a peak incidence between 14-18 years of age for females and 19-25 years for males (Sanders, Maradit, Bryan, Larson, et al., 2016). Incidence rates of ACL injury depend on the population being studied, with a younger, more active population likely to have a higher rate of ACL injury (Mall et al., 2014). ACL injury rates in amateur and professional athletes range from 0.03% to 1.62% and 0.15% to 3.67% respectively (Moses et al., 2012).

ACL reconstruction (ACLR) rates are often used as surrogates for ACL injury rates (Granan et al., 2008). The annual incidence of ACLR surgery in New Zealand (NZ) between 2009–2016 was 58.2 per 100 000 person-years (Sutherland et al., 2019) – a 58% increase since 2005 (Gianotti et al., 2009) – with a peak incidence in the 15-19 year age group for females and the 20-24 year age group for males (Sutherland et al., 2019). Significant increases in ACLR rates, with similar peak incidence trends, have also been reported in Australia (Zbrojkiewicz et al., 2018), the US (Buller et al., 2014; Herzog et al., 2018), the United Kingdom (Abram et al., 2020; Nogaro et al., 2020), and Italy (Longo et al., 2020). Multiple factors have likely contributed to increased rates of ACL injury and ACLR, including greater injury reporting, advances in diagnostics, early sports specialisation in youth and adolescents, higher participation rates in at-risk activities, a greater number of surgeons providing ACLR, and evolving patient

treatment preferences (Abram et al., 2020; Sanders, Maradit, Bryan, Larson, et al., 2016; Sutherland et al., 2019). As not all ACL injuries are formally diagnosed and not all ACL injuries proceed to reconstruction, the true incidence of ACL injury is likely significantly higher than the ACLR rate (Janssen et al., 2011).

The majority of sporting ACL injuries in NZ that undergo ACLR are from a non-contact mechanism during team ball-sports such as rugby, football, and netball (Gianotti et al., 2009; New Zealand ACL Registry, 2021). The percentage of ACLR from sports injuries in NZ increased from 65% to 76% from 2000-05 to 2006-16 (Sutherland et al., 2019). Between 2009 and 2019, the Accident Compensation Corporation (ACC) of NZ received 23,352 claims for sports-related ACL injuries, with ACC funding 20,069 ACLR surgeries (ACC, 2021a), indicating over 85% of ACL injuries during that period proceeded to ACLR, which is a higher percentage than previously reported (Cevallos et al., 2021; Kakavas et al., 2021).

1.2 The Accident Compensation Corporation of New Zealand

New Zealand (NZ) implemented the worlds first, and only, no-fault personal injury insurance scheme in 1974 (Todd, 2011), which is governed by the Accident Compensation Act of 2001 (Connell, 2019), and administered by the Accident Compensation Corporation of NZ. The scheme provides insurance to all NZ citizens, residents, and temporary visitors for physical and mental injuries that can be causally linked to an accident event (Skinner, 2007; Todd, 2011). Once a claim is accepted for cover, the injured person can easily access entitlements, including medical treatment, rehabilitation, and earnings-related compensation (ERC) (Duncan, 2019). Claimants are only eligible to receive ERC if they were in paid employment at the time of their injury. Being in receipt of ERC further entitles a claimant to fully funded vocational rehabilitation (VR), which often includes physiotherapist-led functional rehabilitation (ACC, 2021c). People not in paid employment at the time of their injury are not entitled to receive ERC but are still entitled to receive ACC-funded treatment and non-vocational rehabilitation (Flood, 2000). In return for being able to access entitlements, claimants forgo the right to sue for damages arising out of any personal injury (Bismark & Paterson, 2006).

ACC directly purchases primary medical services and other non-urgent treatment, including physiotherapy, for claimants (French et al., 2001). While ACC is the primary funder of private physiotherapy services in NZ for accident-related conditions (Reid & Larmer, 2007), the ACC payment often does not meet the full cost of the treatment, which can result in the provider charging the patient a co-payment (Fitzjohn, 2007). ACC has historically placed limits on the number of physiotherapy treatments it would fund for a musculoskeletal injury e.g. the maximum number of treatments was 16 for an ACL injury. These treatment limits were the result of multiple workshops throughout NZ, where physiotherapists debated the appropriate number of treatments for approximately 150 of the most common musculoskeletal injuries. Once a consensus was reached on an appropriate number of treatments, agreement from ACC was sought to fund that number of treatments for that injury (P. Larmer, personal communication, October 27, 2022).

Once an injured person has received the allocated number of physiotherapy treatments, the provider is required to submit their clinical records and a completed ACC32 form to ACC to request funding for additional treatments. ACC's Clinical Advisor team, who are often physiotherapists themselves, review the submitted information and recommend the request be either approved or declined. If the request is declined, the patient is then liable for the full cost of any further physiotherapy treatments.

As a means to promote quality improvement, ACC requires physiotherapists working under the Allied Health contract to collect validated outcome measures relevant to the patients condition (ACC, 2021b). However, ACC has no process to ensure physiotherapists are regularly collecting this outcome data, nor does it routinely collect and collate this data from providers. Approximately 45% of private-practice physiotherapists in NZ do not work under the Allied Health contract, instead invoicing ACC under the Cost of Treatment Regulations, and are therefore not required by ACC to collect patient outcome measures (F. Wilkins, personal communication, August 13, 2022). There is also no expectation of physiotherapists in NZ to regularly collect objective strength measures or functional performance data during a course of treatment. As such, when physiotherapists apply to ACC to fund additional

treatments, Clinical Advisor decisions are often based solely on the subjective information contained in the physiotherapist clinical records.

For conditions not covered by ACC, New Zealand's taxation funded, centrally organised public health service aims to achieve universal coverage, equal access to services, and efficiency of public services (Bohm et al., 2013; Lameire et al., 1999). However, persistent socio-demographic inequalities contribute to disparate outcomes across all areas of the NZ healthcare system (Goodyear-Smith & Ashton, 2019; Jatrana & Crampton, 2009). People in NZ can use private medical insurance or self-fund private medical treatment for any non-accident related condition; however, the cost of treatment remains a barrier to accessing healthcare services for a significant number of people in NZ (Jatrana & Crampton, 2009).

1.3 Cost of Anterior Cruciate Ligament Injuries

The management of ACL injuries places a significant financial burden on the NZ healthcare system – a burden met almost exclusively by ACC. Between 2009 and 2019, ACL injuries accounted for <1% of all sports related injuries; however, ACL injuries accounted for >10% of total sports injury claim costs (ACC, 2021a). Between 2000 and 2005, the average cost to ACC for treatment of an ACL injury was $11,157, including specialist consultations, surgery, post-operative rehabilitation, and ERC (Gianotti et al., 2009). From 2016 to 2021, the total cost to ACC of all active ACL injury claims exceeded $350,000,000 (ACC, 2021a), with surgical costs and ERC accounting for 53% and 31% of total costs respectively. In the US, where up to 350,000 ACLR are completed annually at an average cost of US$24,000 per ACLR (Bokshan et al., 2019; Burroughs et al., 2021), total medical costs including diagnosis, surgical reconstruction, and postoperative rehabilitation of ACL injuries are estimated at $3 billion per year (Luc et al., 2014). In Australia, the estimated direct costs of primary ACLR in 2014-15 were $142 million, which does not include the rehabilitation, disease burden, and societal costs associated with the injury (Zbrojkiewicz et al., 2018). ACLR appears to be a more cost-effective management strategy than non-ACLR, with total lifetime costs to society following an ACLR estimated to be US$38,000, compared with an estimated US$88,000 for non-ACLR (Farshad et al., 2011; Mather et al., 2014; Mather et al., 2013).

1.4 How is an Anterior Cruciate Ligament Injury Managed?

Deciding how an ACL injury is managed should be a shared decision-making process between the patient and their healthcare team, with patient goals and expectations driving the final decision (Diermeier et al., 2020). Patient- and injury-specific factors, including age, gender, concomitant injury, pre-injury activity levels, and recurrent episodes of knee instability, may influence the decision-making process (Grevnerts et al., 2020; Grevnerts et al., 2021; Sanders, Maradit, Bryan, Kremers, et al., 2016). Outcomes following ACL injury are not predictable and satisfactory outcomes can be achieved with one of three treatment pathways (Filbay & Grindem, 2019):

1. Early ACLR as first-line treatment, followed by post-operative rehabilitation.
2. Pre-operative rehabilitation, followed by ACLR and post-operative rehabilitation.
3. Conservative management, with rehabilitation as the first-line treatment (followed by ACLR if clinically indicated and post-operative rehabilitation).

Early ACLR is typically advocated as a means to safely return to pre-injury activity levels and preserve long-term knee joint health in young, active people (Diermeier et al., 2020; Sherman et al., 2021). While early ACLR can increase the likelihood of returning to pre-injury activities (Muller et al., 2021), this outcome is far from guaranteed (Ardern et al., 2014). Early ACLR is also associated with a greater risk of revision ACLR, potentially because of an early return to pre-injury activities or insufficient time for pre-ACLR rehabilitation (Ding et al., 2022; Snaebjörnsson et al., 2019). Early ACLR can reduce the risk of secondary meniscal tears (Petersen et al., 2022; Snoeker et al., 2019), with a longer delay to ACLR increasing the risk for subsequent meniscal and chondral injury, likely due to recurrent instability events (Chavez et al., 2020; Hagmeijer et al., 2019; James et al., 2021; Mehl et al., 2019; Prodromidis et al., 2021; Riepen et al., 2022; Sommerfeldt et al., 2018). Meniscal and chondral injuries at the time of ACLR are associated with worse long-term patient outcomes (Pedersen et al., 2020). Despite undergoing ACLR, a significant number of people will go on to develop knee joint osteoarthritis (OA) (Kvist et al., 2020; Webster & Hewett, 2022), and while early ACLR may result in a lower incidence of radiographic knee OA at long-term follow-up, the effect on symptomatic knee joint OA is not as clear (Kvist et al., 2020; Sanders, Kremers, et al., 2016). Ten-year outcome data from the Swedish Knee

Ligament Registry reveals a higher proportion of patients treated with early ACLR report acceptable knee function and superior overall knee function compared with delayed ACLR, with no additional benefit of delayed ACLR over no ACLR (Bergerson et al., 2022). Therefore, the evidence regarding the benefits of early ACLR verses delayed ACLR remains equivocal (Ferguson et al., 2019).

Pre-operative rehabilitation, followed by ACLR and post-operative rehabilitation is a more recently developed strategy to manage ACL injury (Alshewaier et al., 2017), and can result in superior outcomes compared to patients who do not undertake the pre-operative rehabilitation component (Failla et al., 2016; Grindem, Granan, et al., 2015). Several systematic reviews have shown pre-ACLR rehabilitation improves clinical measures and patient-reported outcomes following ACLR (Carter et al., 2020; Giesche et al., 2020; Potts et al., 2022). Although there is good evidence for pre-ACLR rehabilitation, almost 40% of surgeons performing ACLR in Australia do not consider pre-operative rehabilitation important (Ebert et al., 2019), which may negatively impact patient engagement in pre-ACLR rehabilitation.

Conservative management of an ACL injury typically involves functional and exercise-based rehabilitation to improve lower limb strength and neuromuscular control (Filbay & Grindem, 2019). Longitudinal studies of people with an ACL-deficient knee indicate conservative management, incorporating appropriate rehabilitation and activity modification, can result in satisfactory functional outcomes (Kostogiannis et al., 2007; Meuffels et al., 2009; Muaidi et al., 2007). However, data from Scandinavian Knee Ligament Registries show people with conservatively managed ACL injuries report worse outcomes and require more subsequent knee surgery than people who have undergone ACLR (Melbye et al., 2022; Persson et al., 2022). Conservative versus surgical management of an ACL injury has debated for many years (Farshad et al., 2011; Keays et al., 2022), with several reviews on the topic have been unable to establish a clear benefit of one management strategy over the other (Chalmers et al., 2014; Delincé & Ghafil, 2012; Smith et al., 2014).

If patient goals are not achieved with conservative management, then ACLR may be considered (Diermeier et al., 2020). A significant number of ACL-injured people who initially choose conservative management will eventually decide to undergo delayed

ACLR (Grindem et al., 2014; Sanders, Maradit, Bryan, Kremers, et al., 2016). Results from two recent controlled trials, where ACL-injured patients were randomised to receive either early ACLR or rehabilitation followed by optional delayed ACLR, show 39-50% of patients who initially receive rehabilitation will undergo ACLR within two years of injury because of recurrent instability events (Frobell et al., 2010; Reijman et al., 2021).

1.5 How Are Outcomes Evaluated Following Anterior Cruciate Ligament Reconstruction Surgery?

Outcomes following ACLR can be classified as clinical (strength, range of movement etc.), functional (hop test performance, return to sport etc.), recurrent ACL injury, and patient-reported outcome measures (PROMs) (Lynch et al., 2015; Svantesson et al., 2020). Time since ACLR can influence the appropriateness of the outcome measure of interest (Svantesson et al., 2020). For example, reporting rates of knee joint OA within the first 1-2 years of ACLR will likely provide limited data, as the condition may not become established until 5-10 years post-surgery (Webster & Hewett, 2022). In contrast, the outcome of septic arthritis or hardware failure can be established soon after ACLR; therefore a follow-up period of less than six months may be appropriate (Svantesson et al., 2020).

Maximizing joint movement and lower limb strength, in particular quadriceps and hamstrings, following ACLR is essential to the recovery of knee function and reducing the risk of developing knee OA (Arhos et al., 2020; Cristiani, Mikkelsen, et al., 2020; Schmitt et al., 2012; Shelbourne & Klotz, 2006). A person suffering an ACL injury and/or undergoing ACLR has significantly greater odds of developing knee joint OA and subsequently requiring a knee joint replacement than a person who has not suffered an ACL injury (Brophy et al., 2014; Khan et al., 2018; Poulsen et al., 2019; Suter et al., 2017). However, in the short-, medium-, and long-term, quadriceps strength of the affected limb in people undergoing ACLR remains lower than the unaffected limb, possibly indicating inadequate or inappropriate rehabilitation (Brown et al., 2021; Myklebust et al., 2003; Petersen et al., 2014; Tengman et al., 2022). While single leg hop tests are commonly used to assess functional performance and to determine readiness for RTS after ACLR (Barber-Westin & Noyes, 2011), hop test performance

does not always correlate with lower limb strength, nor does it consistently predict a successful RTS or identify risk of re-injury (Davies et al., 2020).

PROMs provide an objective measure of a subjective construct by capturing how the patient believes the condition and treatment has impacted their life (Haywood, 2006; Kyte et al., 2015). PROMs to assess outcome after ACLR include measures of symptoms and function, activity level, health related quality of life, RTS, and psychological status (Lynch et al., 2015; Svantesson et al., 2020). Although over 50 PROMs are available to assess the ACL deficient knee (Johnson & Smith, 2001), the Knee Injury and Osteoarthritis Outcome Score (KOOS) and Marx Activity Rating Scale (MARS) are often recommended, and utilised, following ACL injury and ACLR (Kanakamedala et al., 2016; Wang et al., 2010; Wera et al., 2014).

The KOOS was developed in Sweden in 1998 to assess short- and long-term patient outcomes following a knee injury that could potentially lead to OA (Roos et al., 1998) (Appendix G). The KOOS consists of 42 questions across five subscales – Symptoms, Pain, Activities of Daily Living, Sports and Recreation, and Quality of Life – with each subscale scored separately from zero (extreme knee problems) to 100 (no knee problems) (Collins et al., 2011). An aggregate score is not routinely calculated to allow analysis and interpretation of the five dimensions separately (Roos & Lohmander, 2003); however, a sum of four subscales (Symptoms, Pain, Sports and Recreation, and Quality of Life) has been used to evaluate outcomes after ACLR (Frobell et al., 2010; Frobell et al., 2013). Although not specific to patients with an ACL injury, the KOOS has been reported to be a valid and reliable tool for measuring outcomes following ACLR (Collins et al., 2016; Roos et al., 1998) and is commonly used by ACL registries (Maletis et al., 2011). Primary ACLR improves all subscales of the KOOS in the short- (3-24 months), medium- (five years) and long-term (20 years) (Ahldén et al., 2012; Heijne et al., 2015; Hill & O'Leary, 2013; Lind et al., 2009; van Yperen et al., 2018) – in particular the Sport and Recreation subscale, which highlights the importance of knee stability for sports activities (Winkler et al., 2023).

The MARS is an activity rating scale that was developed and validated in ACL patients by a group of US Orthopaedic surgeons (Marx et al., 2001) (Appendix H). The MARS, which is not disease-specific to ACL injury, measures the frequency of participation in

ACL-dependent activities i.e. running, cutting, decelerating, and pivoting, within the previous 12 months (Collins et al., 2011). The frequency of each activity is scored from zero to four, then added giving a total score from zero to 16, with higher scores representing higher activity levels (Cameron et al., 2015). The psychometric properties of the MARS have not yet been fully established, which may limit its usefulness in a research setting (Collins et al., 2011; Letchford et al., 2012). Primary ACLR does improve pre-surgery MARS scores in NZ (New Zealand ACL Registry, 2021), although international research shows over 50% of patients do not achieve their pre-injury MARS score two years after ACLR (Dunn et al., 2010).

PROMs are typically reported as mean and standard deviation of the change in score, which may lack clinical relevance for users of the tool (Tubach, Wells, et al., 2005). As such, the patient acceptable symptom state (PASS) maybe a more meaningful outcome for the patient (Tubach, Ravaud, et al., 2005). The PASS is defined as the score beyond which patients consider themselves well and their symptoms acceptable (Comins et al., 2020; Tubach et al., 2007). Following ACLR, 55% and 66% of patients perceive their symptoms as acceptable at six months and two years respectively (Ingelsrud et al., 2015), and a higher percentage of patients perceive their symptoms as acceptable after ACLR compared to conservatively managed patients (Persson et al., 2022).

Healthcare registries collect data regarding surgical technique, adverse events, and patient outcomes following medical procedures (Lind et al., 2009). Registries provide a mechanism to improve patient outcomes via feedback to clinicians, optimise quality control, and to identify prognostic factors associated with both positive and negative outcomes (Senorski, Svantesson, Engebretsen, et al., 2019). The first national ACL registry was developed in Norway in 2004, followed by registries in Sweden and Denmark in 2005 (Granan, Forssblad, et al., 2009). Collective data from these registries has been used in many studies to evaluate factors associated with PROMs following ACLR (Senorski, Svantesson, Baldari, et al., 2019). PROMs are often used by ACL registries as they minimise potential bias in the data (Granan et al., 2008).

The NZ ACL Registry, which commenced in 2014, currently enrolls 90% of ACLR patients in NZ, with approximately 15,000 patients enrolled as of mid-2021 (New Zealand ACL Registry, 2021). Since 2017, it is mandatory for all Orthopaedic surgeons

in NZ who perform ACLR to actively participate in the Registry to achieve recertification (Rahardja et al., 2020). The NZ ACL Registry collects KOOS and MARS scores pre-operatively, then at 6-, 12-, 24-, and 60-months post-ACLR, with an estimated pre-injury MARS score also collected (New Zealand ACL Registry, 2021). NZ ACL Registry KOOS and MARS scores at 6-, 12-, and 24-months after ACLR are equivalent to scores from other international registries, in terms of absolute values and improvement over time (Hill & O'Leary, 2013; Kvist et al., 2014; New Zealand ACL Registry, 2021).

1.6 What Factors Influence Patient Outcomes Following Anterior Cruciate Ligament Reconstruction Surgery?

The outcome of an ACLR is influenced by multiple factors, including, but not limited to, surgical technique (King et al., 2020; Rahardja et al., 2020; Rambaud et al., 2022), concomitant injury (Muller et al., 2021; Senorski, Svantesson, Baldari, et al., 2019), psychosocial factors (Grindem, Risberg, et al., 2015; Rambaud et al., 2022; Webster et al., 2019), previous knee injury (Scherer et al., 2016), pre-injury activity level (de Valk et al., 2013; Muller et al., 2021), lower limb strength and functional performance (Middlebrook et al., 2021; Paterno et al., 2017; Scherer et al., 2016), patient lifestyle choices (de Valk et al., 2013; Middlebrook et al., 2021), insurance status (Beletsky et al., 2020; Chava et al., 2022), ethnicity (Bram et al., 2020), and socio-economic status (Ziedas et al., 2021).

Three factors also shown to consistently influence outcomes following ACLR are patient age, gender, and the time between ACL injury and ACLR (Anderson et al., 2016; de Valk et al., 2013). Younger age at the time of ACLR is associated with higher PROM scores (Scherer et al., 2016; Senorski, Svantesson, Baldari, et al., 2019), an increased rate of return to sport (RTS) (Muller et al., 2021), greater hop test performance (Webster & Feller, 2017), and higher activity levels (Senorski, Svantesson, Baldari, et al., 2019) following surgery. Younger age at ACLR is also associated with an increased risk of revision ACLR (Cristiani et al., 2021), which likely reflects the high rate of young people returning to ACL-dependent activities following their primary ACLR (Webster & Feller, 2018).

Multiple studies and systematic reviews have examined the effect of gender on outcomes following ACLR. Patient-reported outcomes and functional performance scores following ACLR are worse for females compared to males (Cristiani, Mikkelsen, et al., 2020; de Valk et al., 2013; Senorski, Svantesson, Baldari, et al., 2019; Senorski et al., 2018; Webster & Feller, 2017), although males can experience higher re-rupture rates (Mok et al., 2022). In contrast, the risk for graft failure or contralateral ACL injury is reportedly not different between males and females (Patel et al., 2021; Ryan et al., 2014). Overall, outcomes following ACLR are not equal between genders, with females either the same or worse compared to males – outcomes for females rarely, if ever, exceed their male counterparts (Ellison et al., 2021; Tan et al., 2016).

As with gender, multiple studies have reported how the length of time between ACL injury and ACLR may potentially influence patient outcomes. Systematic reviews on the topic have shown no difference in outcomes between and early and delayed ACLR (Smith et al., 2010; Lee et al., 2018), and higher post-surgery activity levels with early ACLR (de Valk et al., 2013), with methodological differences between the reviews likely contributing to the equivocal findings. A longer delay to ACLR can be associated with a decreased RTS (Muller et al., 2021), decreased likelihood of achieving a PASS score on PROMs (Forsythe et al., 2021), and an increased risk of revision surgery (Cristiani et al., 2021). A longer delay to ACLR is associated with a higher incidence of meniscal and chondral pathology at the time of surgery, which likely contributes to the negative effect on patient outcomes (Cristiani, Janarv, et al., 2020; Ralles et al., 2015). There are no universally accepted definitions of early or delayed ACLR, with early ACLR defined as within two days to seven months of ACL injury and delayed ACLR defined as three weeks to 24 years (Anderson et al., 2016), which makes drawing definitive conclusions from the research in this area difficult.

As previously stated, rehabilitation can have a positive influence on patient outcomes following ACLR (Culvenor & Barton, 2018; Janssen et al., 2018). Pre- and post-surgical rehabilitation has been shown to improve post-operative outcomes for patients undergoing ACLR (Carter et al., 2020; Grindem, Granan, et al., 2015). Despite no consensus on the optimal components of a post-ACLR rehabilitation programme (Lobb et al., 2012), systematic reviews support the use of immediate mobilisation after surgery, open and closed kinetic chain exercises to increase lower limb strength,

neuromuscular electrical stimulation to facilitate muscle activation, and proprioceptive re-training to improve neuromuscular control (Andrade et al., 2019; Kruse et al., 2012; Risberg et al., 2004; van Grinsven et al., 2010).

Effective ACLR rehabilitation involves a multi-disciplinary team working collaboratively towards agreed goals (Wade, 2020), and should include good communication between the Orthopaedic surgeon and rehabilitation provider (Filbay & Grindem, 2019); (van Melick et al., 2016). Optimal ACLR rehabilitation should also involve assessment of the patient experience and functional performance at regular intervals (Grindem, Risberg, et al., 2015), as this helps develop and maintain patient motivation (Risberg et al., 2016), while providing real-time, objective feedback to the rehabilitation provider on the effectiveness of the rehabilitation programme. Despite near universal acceptance of its importance, post-ACLR rehabilitation remains sub-optimal for some patients, and incomplete rehabilitation likely contributes to worse patient outcomes following ACLR (Ebert et al., 2018; Edwards et al., 2018). An underutilisation of rehabilitation following ACLR can be due to multiple factors, including premature discharge, inadequate or inappropriate content, financial or access barriers, patient non-compliance/adherence, and a lack of patient knowledge regarding the importance of rehabilitation (Cailliez et al., 2012; Dunphy & Gardner, 2020; Grindem, Arundale, et al., 2018; Risberg et al., 2016).

1.7 Rehabilitation and Physiotherapy Treatment Following Anterior Cruciate Ligament Reconstruction

Physiotherapy is the process by which movement and physical function are treated when an individual experiences injury, illness, or disability, and is an important component of rehabilitation following soft tissue injury in the knee (Clark, 2015). Due to their scientifically-based clinical skills, physiotherapists are the health professionals most often involved in the delivery and oversight of post-ACLR rehabilitation (Clark, 2015; Glattke et al., 2021). A recent survey of over 300 ACLR patients in Australia reported over 97% received rehabilitation from a physiotherapist (Walker et al., 2021), and in NZ, physiotherapists are the lead providers of functional rehabilitation following ACLR (ACC, 2021b). In a research setting, ACLR rehabilitation is most often delivered by a physiotherapist (Dunphy et al., 2020). As physiotherapists are the main providers

of ACLR rehabilitation, the number of post-ACLR physiotherapy treatments, and duration of that treatment, can provide a reasonable indication of the dosage of rehabilitation received following ACL surgery.

The quantity of post-operative physiotherapy visits for community-based ACLR patients can range from <5 to >50 (Dempsey et al., 2019; Feller et al., 2004; Han et al., 2015; Heijne & Werner, 2010). Retrospective studies indicate ACLR patients in the US receive an average of 17-19 physiotherapy treatments following surgery (Burroughs et al., 2021; Christensen et al., 2017; Miller et al., 2017; Zhang et al., 2015). From a sample of over 7000 ACLR patients in NZ, the average number of pre- and post-ACLR treatments received was reported as 14 and 12 respectively (Gianotti et al., 2009), although it is not clear if these were exclusively physiotherapy treatments or also included surgeon reviews as well. As such, the number of physiotherapy treatments patients receive following ACLR in NZ is currently uncertain.

Following ACLR, a greater number of physiotherapy treatments has been associated with higher PROM scores (Christensen et al., 2017; Han et al., 2015), increased odds of RTS (Han et al., 2015), and a decreased risk of revision surgery (Miller et al., 2017). However, other studies report the quantity of post-ACLR physiotherapy treatment has no effect on PROM scores, knee strength, and graft rupture rates (De Carlo & Sell, 1997; Feller et al., 2004; Vincent et al., 2017). Although a dose-response relationship between the amount of physiotherapy treatment following ACLR and patient outcomes might be expected, the optimal number of physiotherapy treatments following ACLR remains unknown (Walker et al., 2020).

There are clear parallels between the level of supervision during post-ACLR rehabilitation and the quantity of post-ACLR physiotherapy treatment received (Gamble et al., 2021; Uchino et al., 2022). Multiple systematic reviews have reported no difference in self-reported knee function, sports participation, knee strength and range of motion, sagittal plane knee laxity, single leg hop performance, or quality of life between patients who have more intensive supervised rehabilitation following ACLR and those who have less supervised, or home-based, rehabilitation (Kruse et al., 2012; Lobb et al., 2012; Risberg et al., 2004; Wright et al., 2008). A recent scoping review concluded a moderately or minimally supervised rehabilitation programme is at

least as effective as a fully supervised high-frequency rehabilitation programme (Walker et al., 2020).

ACLR rehabilitation is recommended to last 9-12 months – dependent on the goals of the patient – although criterion-based progressions are now favoured over time-based progressions (van Melick et al., 2016). However, retrospective studies from the US report ACLR rehabilitation only lasts between 127 and 171 days (Christensen et al., 2017; Dempsey et al., 2019; Miller et al., 2017). From a NZ context, the duration of post-operative rehabilitation for people who have undergone ACLR has not been previously reported.

The overall duration of physiotherapy treatment i.e. number of days from first treatment to last treatment, after ACLR can influence patient outcomes. A longer duration of rehabilitation is associated with increased knee flexor and extensor strength (Królikowska, Sikorski, et al., 2018a), greater leg symmetry during jumping tasks (Królikowska, Czamara, & Reichert, 2018), and an increased rate of RTS (Yabroudi et al., 2021). Longer, more comprehensive, post-ACLR rehabilitation is associated with greater limb symmetry during hop tests and lower limb strength, which translates into an increased rate of RTS (Ebert et al., 2018; Edwards et al., 2018). However, longer post-ACLR rehabilitation does not improve jumping performance in female soccer players (Arundale et al., 2019) or the peak torque angle in the muscles of ACL-reconstructed knees (Krolikowska et al., 2019). At least six months of structured supervised rehabilitation is associated with more favourable outcomes after ACLR, with 9-12 months of supervised rehabilitation likely to offer further benefits (Walker et al., 2020).

A number of factors contribute to the overall of dosage of physiotherapy received during a course of treatment, including the length of time of each treatment, the number of treatments, and the length of time those treatments are delivered over (Snodgrass et al., 2014). In the current context, the dosage of physiotherapy treatment is defined as the number of physiotherapy treatments over the period of time those treatments are delivered. However, the duration of each individual physiotherapy treatment will influence the overall dosage of treatment. For example, if two patients both receive 10 physiotherapy treatments, but one patient receives 20

minute treatments and the other patient 40 minute treatments, there will be a significant difference in the overall dosage of treatment received.

A distinction also needs to be made between the dosage of physiotherapy treatment community-based ACLR patients receive compared with the dosage of treatment an ACLR patient may receive as part of controlled research. In a community physiotherapy setting, the dosage of treatment is at the discretion of the treating therapist and potentially influenced by multiple factors (Filbay & Grindem, 2019). Conversely, patients in a controlled trial typically receive a predefined number of treatments, at regular intervals, over a set period of time. A recent scoping review of 14 controlled trials of ACLR rehabilitation reported the median number of physiotherapy sessions per week was 3 x 60 minutes, over interventions ranging from 3-36 weeks (Dunphy et al., 2020). As such, the dosage of physiotherapy used in a controlled trial may not be applicable to a real-world clinical setting.

Physiotherapist opinion regarding the dosage of treatment required following ACLR can vary dependent on the healthcare environment that treatment is provided in. Australian therapists indicate between 21 and 35 treatments are necessary in the 12 months post-ACLR (Ebert et al., 2019), whereas the majority of Flemish and Greek physiotherapists suggest 41-60 treatments are needed between six and nine months after ACLR (Dingenen et al., 2021; Korakakis et al., 2021). One reason for this variability could be the different funding models for physiotherapy treatment in each country i.e. privately verses publicly funded, which has been shown to influence provider behaviour regarding the dosage of treatment provided (Barasa et al., 2021). Although physiotherapists are the main providers of rehabilitation following ACLR in NZ (ACC, 2021b), the quantity and duration of treatment they believe is necessary after ACLR is currently unknown. What is also not clear is if the quantity and duration of treatment physiotherapists believe is required after ACLR corresponds to the actual quantity and duration of treatment patients receive after ACLR, as there is no published data regarding this relationship. The opinions and practice beliefs of physiotherapists regarding ACLR rehabilitation are also important, as they provide an indication of physiotherapist awareness of best-practice guidelines, and whether patients are receiving the recommended dosage of ACLR rehabilitation (Dingenen et al., 2021; Ebert et al., 2019).

1.8 Summary

An ACL rupture is a significant injury with significant consequences. The number and rate of ACL injuries is increasing, with the costs to manage the injury, and to society overall, increasing as a result. Outcomes following ACL injury are frequently unpredictable, suboptimal, and influenced by multiple factors. No two ACL injuries are identical, which means the true natural history of an ACL injury cannot be confidently described (Beynnon, Johnson, et al., 2005). Accordingly, there is no one treatment pathway that is suitable for all ACL injuries. Rehabilitation is an essential part of any potential pathway for managing an ACL injury, with physiotherapy treatment often a fundamental component of the overall rehabilitation programme.

From a NZ perspective, the quantity and overall length of physiotherapy treatment received has not been quantified, despite this data being readily available via ACC. Patient-reported outcomes following ACLR are also collected in NZ; however, the NZ ACL Registry has no visibility of the dosage of physiotherapy treatment patients receive. Therefore, the relationship between the dosage of physiotherapy treatment following ACLR in and patient-reported outcomes in NZ is yet to be defined.

A patients rehabilitation journey following ACLR is influenced by many things and there is considerable variability in the dosage of physiotherapy treatment required between individuals to restore functional ability. Although recommendations have been made regarding the dosage of physiotherapy treatment necessary following ACLR, the actual quantity of treatment patients receive, both pre- and post-ACLR, has not been widely reported. There are also marked inconsistencies between the recommended dosage of treatment, the actual dosage of treatment patients receive, and the dosage of treatment physiotherapists report they provide to patients. Several different physiotherapist populations around the world have been surveyed on their beliefs and attitudes regarding post-ACLR rehabilitation; however, the opinions of NZ physiotherapists on the topic remain unknown.

1.9 Significance of this Thesis

ACC is an integral component of the NZ healthcare system, providing the funding for timely access to medical treatment and rehabilitation services for accident-related

conditions. While legislative barriers exist to safeguard the long-term viability of the scheme, such barriers can at times limit a patients access to necessary and appropriate treatment. ACC and physiotherapists in NZ are intrinsically linked, as one is the predominant funder of treatment for accident-related conditions and the other is the predominant provider of treatment for accident-related conditions. Funding decisions regarding physiotherapy treatment are based on physiotherapist clinical records, with no objective evidence to assist the decision-making process. ACC funds over 100 million dollars of physiotherapy care in NZ annually; however, the absence of objective outcome data results in ACC having little insight into the effectiveness of that treatment and overall patient outcomes.

Physiotherapists should have knowledge of the dosage of treatment that may increase the likelihood of a positive outcome following injury. The dosage of treatment received may indicate further treatment is required, or further investigation or onward referral is necessary. However, it is important the expected dosage of physiotherapy treatment required for an injury be based on empirical data, rather than hypothetical scenarios, as this ensures a level of robustness to any clinical decision making.

Physiotherapist beliefs are important as they provide insight into how effective the translation of research knowledge into clinical practice is. If the beliefs and practices of physiotherapists do not align with what research evidence recommends, this may indicate barriers to implementing evidence-based practice are present. Knowledge of physiotherapist beliefs regarding management of a specific injury e.g. ACL injury, also allows for comparisons to be made to actual clinical practice. Discrepancies between what treatment physiotherapists believe is required and what treatment is actually delivered can be highlighted, and possible reasons for those discrepancies explored.

From a personal perspective, there are several motivations for undertaking this research. As a physiotherapist, I am interested in the optimal dosage of treatment required for a given injury, as this may influence decision making on how to manage the injury, guide treatment planning, and assist with clinical decision-making during treatment. I am also interested in the outcomes my patients achieve, as this provides both feedback on the effectiveness of my treatment and objectivity regarding treatment decisions. As a Clinical Advisor at ACC, I am interested in patient outcomes

as these provide objective data when assessing funding requests for additional treatment. ACC is also interested in the relationship between patient outcomes and the treatment purchased, as this allows ACC to consider the overall value of that treatment. My overall goal for this thesis is to improve patient outcomes following ACLR. I believe several factors can help achieve this goal: 1) establishing the quantity of physiotherapy treatment NZ ACLR patients are currently receiving, and how long they are receiving that treatment for, 2) knowing if there is an optimal number of physiotherapy treatments, and overall duration of physiotherapy treatment, that leads to the best outcome, 3) increasing the awareness and utilisation of outcome measures by physiotherapists.

1.10 Objective, Aims, and Structure of this Thesis

The primary research question for this thesis is:

- What is the relationship between the dosage of physiotherapy treatment and patient outcomes following primary ACLR in NZ?

Several sub-questions emerge from the primary research question:

- What is the quantity and duration of physiotherapy treatment received by patients following primary ACLR in NZ?
- Does the quantity and duration of physiotherapy treatment received by NZ ACLR patients align with the beliefs and practices of NZ physiotherapists delivering the treatment?
- Do the beliefs and practices of NZ physiotherapists regarding ACLR rehabilitation influence the quantity and duration of post-ACLR physiotherapy treatment?

The main body of this thesis consists of four separate, but inter-linked, studies (Figure 1.1). The first study is a descriptive analysis of ACC physiotherapy treatment and rehabilitation data for a cohort of patients following an ACL injury in NZ between 2013 and 2016. The aim of the study is to describe the quantity and duration of

physiotherapy treatment patients receive after ACL injury, and prior to and following ACLR.

The second study is a systematic review of published data, with the specific aim to determine if a relationship can be established between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following primary ACLR.

The third study is a quantitative analysis investigating the relationship between the quantity of physiotherapy treatment and patient-reported outcomes following ACLR in NZ. Physiotherapy treatment data from ACC and patient-reported outcome data from the NZ ACL Registry will be used as data sources.

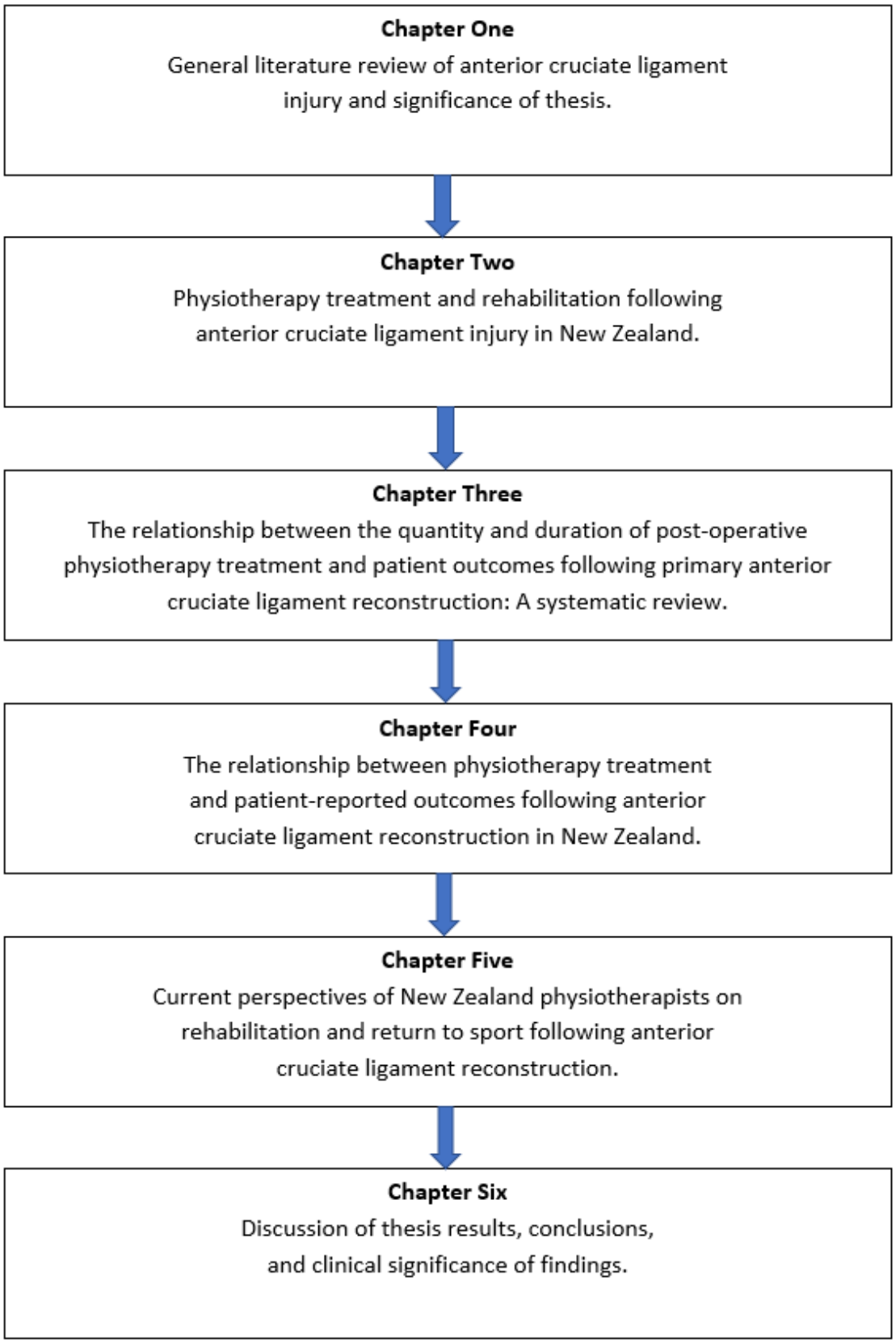
The fourth study is a survey of NZ physiotherapists on their beliefs and practices regarding pre- and post-surgical rehabilitation and return to sport criteria following ACLR. The aims of the study are to determine the dosage of physiotherapy treatment NZ physiotherapists believe is required following ACLR, examine any discrepancies between those beliefs and actual physiotherapy treatment data, and explore NZ physiotherapy practices regarding ACLR rehabilitation.

The last chapter of this thesis will interpret and explain the results from chapters two through five, while providing recommendations for future-state physiotherapeutic management of ACL injury and ACLR in NZ.

Please note that as this thesis is presented in a series of published papers, at times there is necessary repetition of key research in the introduction sections. It is not possible to avoid this.

Figure 1.1

Flow diagram of thesis chapters.



Chapter 2

Physiotherapy Treatment and Rehabilitation Following Anterior Cruciate Ligament Injury in New Zealand

This chapter comprises of the following manuscript:

Fausett, W., Wilkins, F., Reid, D., Larmer, P., & Potts, G. (2019). Physiotherapy treatment and rehabilitation following anterior cruciate ligament injury in New Zealand: Are we doing enough? *New Zealand Journal of Physiotherapy*, *47*(3). 139-149. doi:10.15619/NZJP/47.3.02

To maintain consistency of style throughout the thesis, the manuscript is presented here in a format that differs slightly to the published article (Appendix A).

2.1 Preface

Physiotherapy treatment often forms the mainstay of rehabilitation following ACL injury in NZ. A small number of retrospective studies from other countries have reported the dosage (quantity and duration) of physiotherapy treatment received following ACLR varies widely and may not always be consistent with evidence-based recommendations. The dosage of physiotherapy treatment received following ACL injury and ACLR in NZ has not previously been reported. Knowing the dosage of physiotherapy treatment is the first step on the journey to better understanding the effects of that dosage. Therefore, this study aimed to quantify the dosage of physiotherapy treatment received by NZ patients who had suffered an ACL injury, and the dosage of post-operative treatment received by those patients who proceeded to ACLR.

2.2 Abstract

Physiotherapists are lead providers of rehabilitation following anterior cruciate ligament (ACL) injury in New Zealand. Rehabilitation is considered an essential component following anterior cruciate ligament injuries, but there is considerable variability regarding pre- and post-operative management. This study used data from the Accident Compensation Corporation (ACC) for the years 2013/14 to 2015/16 to gain insight into the physiotherapy management of anterior cruciate ligament injuries in New Zealand. Data were extracted from 647 claims from people with a completed anterior cruciate ligament reconstruction (ACLR) and 221 claims from people with a confirmed ACL injury who did not undergo surgery. In the 12 months following either anterior cruciate ligament injury or surgery, 81% of claimants had fewer than 15 ACC-funded physiotherapy treatments, and 13% of claimants had no ACC-funded physiotherapy treatments. Nine percent of claimants had a previous or subsequent claim for an anterior cruciate ligament injury. Compared to best practice literature, the results indicate a significant number of people in New Zealand received fewer than the recommended number of physiotherapy treatments following anterior cruciate ligament injury. Possible reasons may include the cost of private physiotherapy services, a lack of endorsement from the respective orthopaedic surgeon, decreased patient adherence/motivation and decreased patient understanding of the importance of rehabilitation.

2.3 Introduction

Injury to the anterior cruciate ligament (ACL) of the knee is a common occurrence in an active population (Gianotti et al., 2009; Majewski et al., 2006). Following ACL injury, the two traditional management pathways are 1) early ACL reconstruction (ACLR) surgery followed by rehabilitation and 2) conservative management consisting of rehabilitation, with the option of delayed ACLR if required (Beynnon, Johnson, et al., 2005; Risberg et al., 2004; Zadro & Pappas, 2018). The exact incidence of ACL injury is not known as not all ACL injuries are diagnosed or proceed to surgery (Janssen et al., 2011). ACL surgery rates are often used as surrogate estimates of injury rates (Moses et al., 2012; Sanders, Maradit, Bryan, Larson, et al., 2016). Rates of ACLR are increasing worldwide (Sanders, Maradit, Bryan, Larson, et al., 2016; Zbrojkiewicz et al.,

2018). An increasing ACLR rate is associated with increased work absenteeism, rehabilitation costs, and an increased rate of degenerative knee conditions and knee joint arthroplasty (Barenius et al., 2014; Cinque et al., 2017; Janssen et al., 2011; Khan et al., 2018; Suter et al., 2017).

The Accident Compensation Corporation (ACC) of NZ provides 24-hour comprehensive no-fault accident insurance to compensate the injured person and assist them in returning to independence by covering medical costs, other entitlements, and ensuring timely access to treatment (Flood, 2000). Annually, ACC spends over $25 million on ACL surgeries and over $100 million on physiotherapy services for all injuries (ACC, 2018a). Entitlements and cost of physiotherapy treatment will vary depending on the injured person's work status or capacity, and the contracts held by the treating physiotherapist. ACC purchases physiotherapy treatment in 3 ways: via the cost of treatment regulations, the physiotherapy services contract (ACC, 2018b), or vocational rehabilitation services (VRS). The ACC contribution may not fully cover the cost of treatment via regulation or contract, and some private physiotherapy practices charge a co-payment of up to $50 per treatment (Fitzjohn, 2007). Claimants who are unable to complete work duties and receive earnings related compensation (ERC) are entitled to VRS, which support and facilitate a return to work, are fully funded, and may include physiotherapist-led functional rehabilitation (ACC, 2018c).

Rehabilitation following ACL injury or ACLR should encompass a biopsychosocial approach (Scott et al., 2018), consisting of patient education, physical rehabilitation, and addressing psychological barriers (Filbay & Grindem, 2019; Risberg et al., 2016; Zadro & Pappas, 2018). The physical component of rehabilitation involves restoration of knee range of movement, lower limb strengthening, neuromuscular and proprioceptive retraining, and activity-specific exercises (Adams et al., 2012; Myer et al., 2006). Physical rehabilitation following ACL injury is safe and efficacious (Eitzen et al., 2010), with the ultimate goal of rehabilitation to achieve a sustainable return to pre-injury activities (Risberg et al., 2004). Physiotherapists, with expertise in the function of the musculoskeletal system, have the knowledge and skills to implement and progress the physical and functional components of ACL rehabilitation (van Melick et al., 2016).

A structured pre-operative physical rehabilitation programme is associated with better post-operative functional outcomes (Eitzen et al., 2009; Failla et al., 2016; Logerstedt et al., 2013). Supervised physiotherapy is routinely prescribed following ACL surgery (Han et al., 2015), and supervised rehabilitation can be associated with better outcomes than unsupervised (Christensen et al., 2017). Physical rehabilitation lasting up to 12 months is recommended after ACLR to restore function and stability to the knee (Adams et al., 2012; Zadro & Pappas, 2018), and to optimise post-surgical outcomes (Grindem, Granan, et al., 2015). Recent evidence suggests people may not be completing sufficient post-ACLR rehabilitation before returning to pre-injury activities (Ebert et al., 2018; Grindem, Arundale, et al., 2018). Irrespective of how an ACL injury is managed, a significant percentage of people do not return to pre-injury activity levels (Ardern et al., 2014; Øiestad et al., 2018; Webster & Feller, 2018), or suffer a subsequent ACL injury (Crawford et al., 2013; Lai et al., 2018; Wright et al., 2011).

The content and quality of ACL rehabilitation protocols is highly variable (Ajuied et al., 2014), which may lead to confusion among patients and physiotherapists (Makhni et al., 2016). Patient outcomes following ACL rehabilitation could also be influenced by patient individuality and variability in physiotherapist implementation of specific ACL rehabilitation protocols (Adams et al., 2012; Greenberg et al., 2018; Myer et al., 2006).

The aim of this study was to undertake a retrospective review of a 3-year period of ACC claim data to gain insights into the management of ACL injury in NZ, with a particular focus on the quantity and duration of physiotherapy treatment following injury, and during the pre- and post-operative rehabilitation period.

2.4 Methods

A descriptive methodology was utilised for this study. The study cohort included all claims with an approved ACLR request for the 2013/14, 2014/15, and 2015/16 years (the year being July 1st to June 31st). Claims with an approved ACLR request were assumed to have a confirmed diagnosis of an ACL rupture. ACC claim numbers were used to identify claims. Claims were categorised by whether surgery had been completed (Surgery group) or not completed (Non-surgery group), and stratified by gender and age at date of injury (DOI) (<20, 20-29, 30-39, 40-49, 50+ years old). Using

a random number generator in Microsoft Excel, a sample of 20 claims from each age group and gender, from each year, were selected. Where there were less than 20 claims in an age group and gender for that year, all claims were included in the sample. Convenience sampling was used to ensure the total sample included a similar number of males and females, and all age ranges were equally represented.

For the Surgery and Non-surgery groups, data collected via ACC's internal database and payments system included:

- claimant sex
- date of birth
- age at date of ACL injury
- mechanism of injury (MOI)
- activity being performed when ACL injury occurred
- date of last physiotherapy treatment
- total days earnings related compensation (ERC) days paid under that claim
- whether there was an approved purchase order for vocational rehabilitation in the 12 months following surgery or injury
- whether the client had suffered a previous or subsequent ACL injury.

Additional data collected for the Surgery group included the date of surgery, number of pre-operative ACLR physiotherapy treatments, and number of post-ACLR physiotherapy treatments within 12 months of surgery. Additional data collected for the Non-surgery group included the total number of physiotherapy treatments within 12 months of injury. The 12-month period was chosen as this is the recommended duration of rehabilitation following ACL injury (van Melick et al., 2016). In addition, all claims where the person had undergone ACL surgery more than 364 days after DOI were categorised as 'Delayed surgery', and this group was analysed separately.

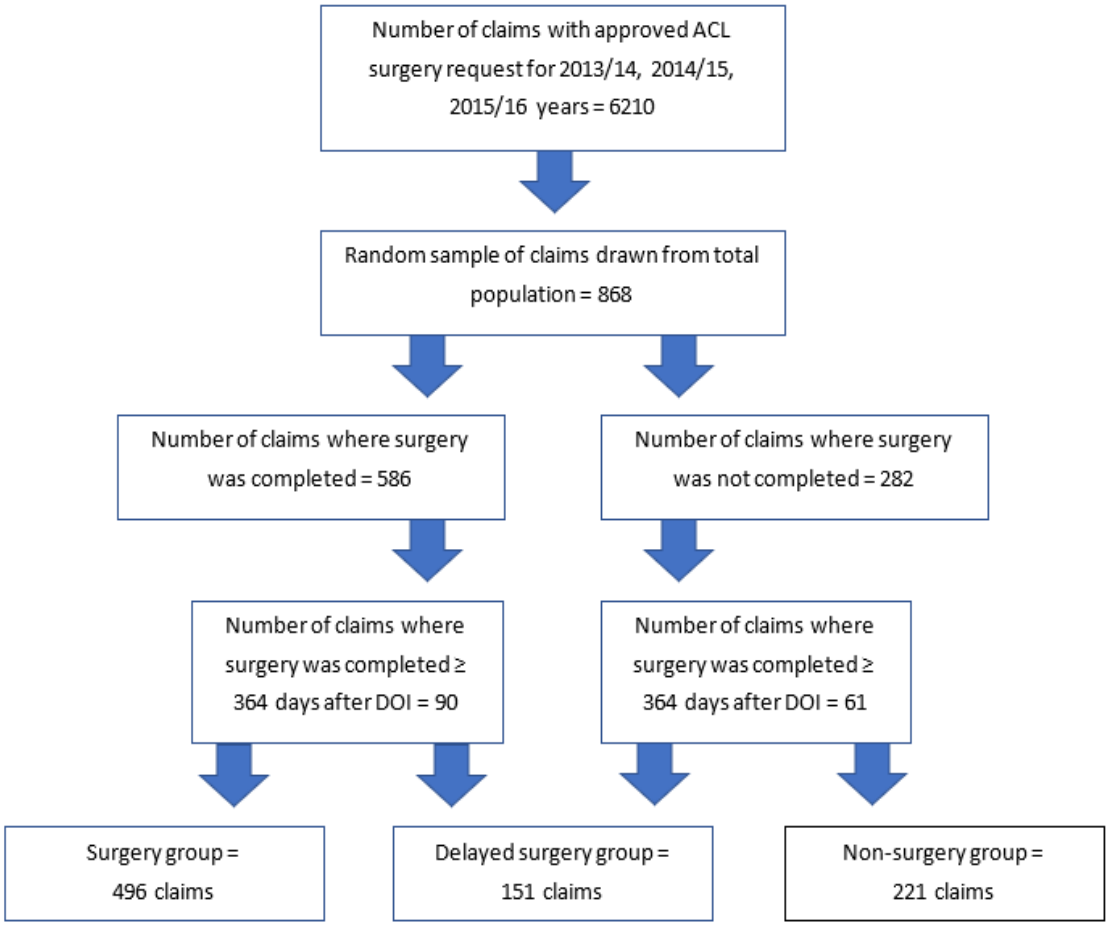
Use of ACC claim data complied with standard ACC consent and legal obligations related to cover. Ethical approval was sought retrospectively; however, the study did not meet the threshold to require ethical approval as all data remained de-identified during collection and analysis.

2.5 Results

The selection of claims for analysis is described in Figure 2.1. From the Surgery group, 2 claims were excluded as the clients had not undergone ACLR, and 1 claim was excluded as the ACL was found intact at the time of surgery. From the Non-surgery group, 6 claims were excluded as the ACL was subsequently revealed to be intact, and 7 claims were excluded as the clients had undergone ACLR within 12 months of injury. Overall, the Surgery, Delayed surgery, and Non-surgery groups represented 8%, 2.5%, and 3.5% of the total number of ACC claims with an approved ACLR request between 2013/14 and 2015/16 respectively.

Figure 2.1

Flow diagram describing sample selection and how each study group was determined.



Across the three groups, average age at DOI was 33.4 ± 13.2 years (range 9-74 years). The percentage of male subjects in the Surgery, Delayed surgery, and Non-surgery groups was 48%, 62%, and 58% respectively. The most common activity being performed when suffering an ACL injury was Sports followed by Recreational activities (Figure 2.2). The most common sport being played when suffering an ACL injury was netball, followed by rugby, soccer, and touch (Figure 2.3), and 74% (642/868) of ACL injuries involved a non-contact MOI.

Figure 2.2

Activity being performed when ACL injury occurred.

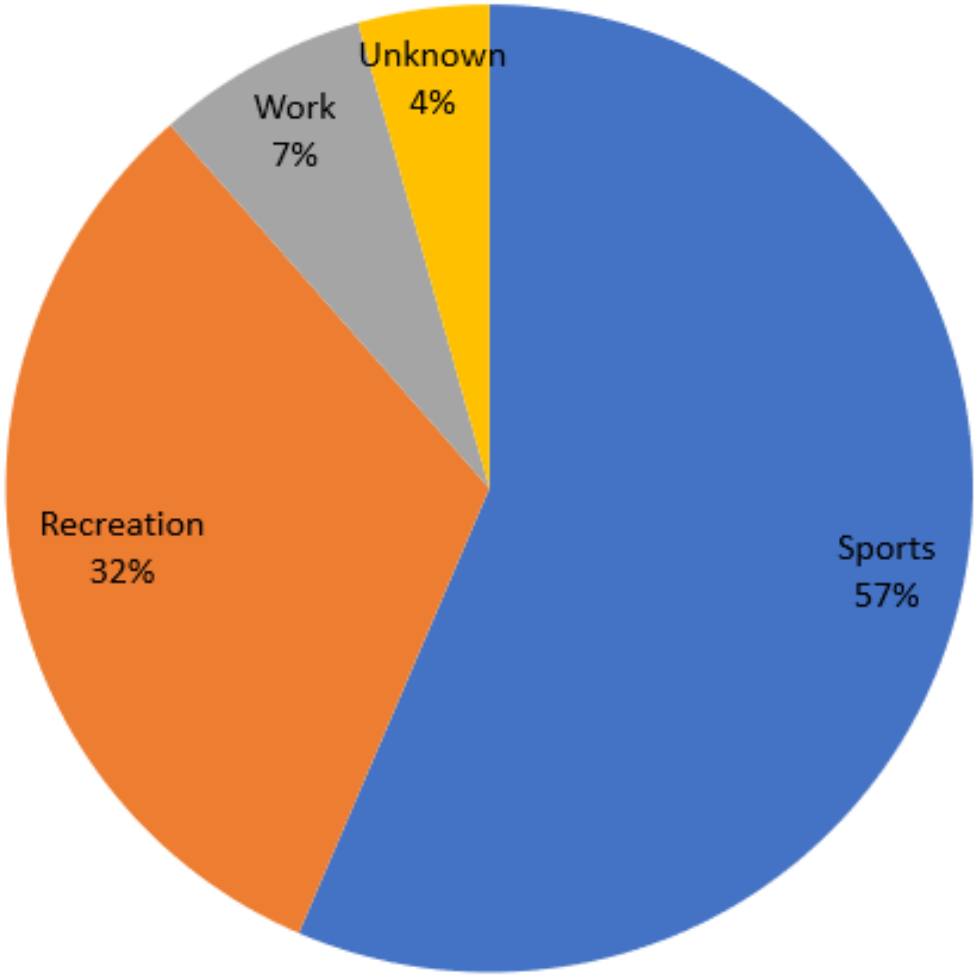
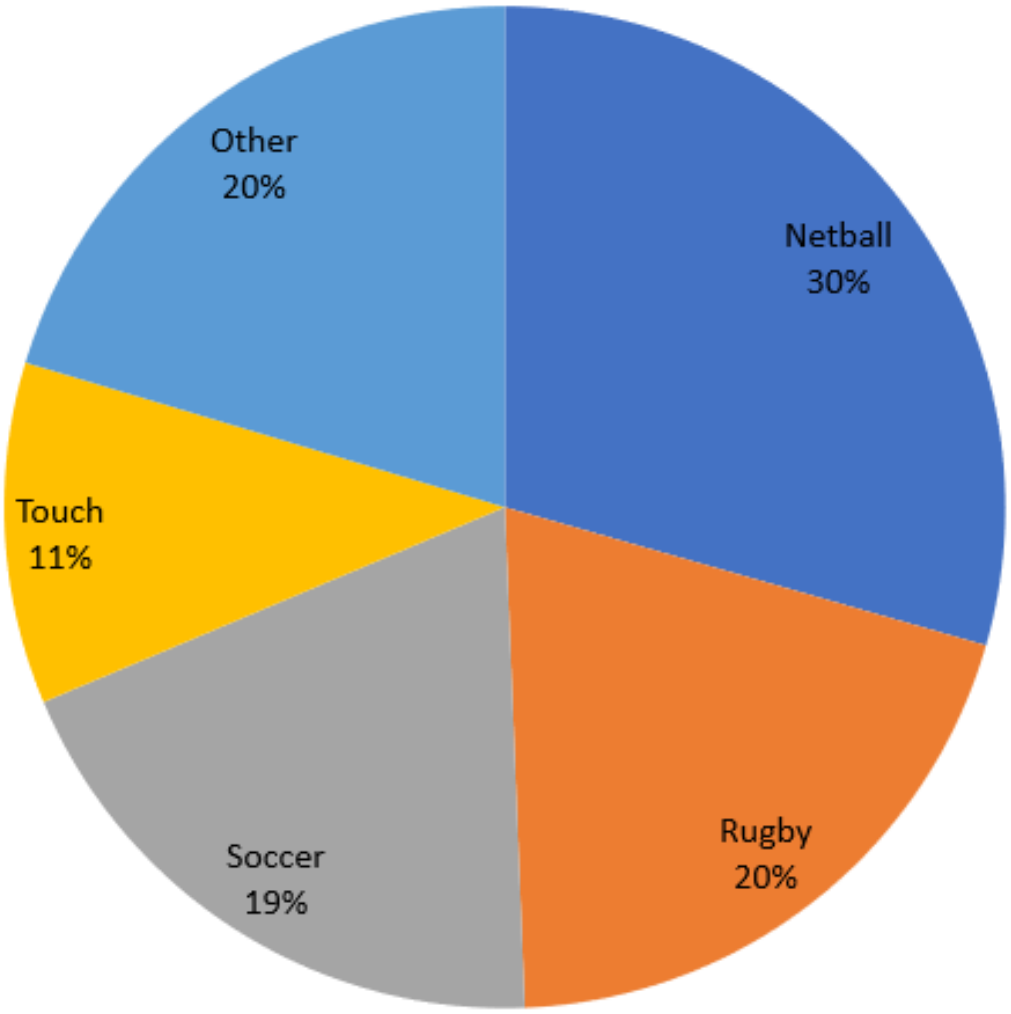


Figure 2.3

Sport being played when ACL injury occurred.



2.5.1 Physiotherapy Treatment

For the Surgery group (n = 496), 120 claims (24.2%) had no pre-ACLR physiotherapy treatments (Figure 2.4). Of the 376 claims (75.8%) with pre-ACLR physiotherapy treatments, the average number of treatments was 7 ± 5 (range 1-33). In the 12 months following ACLR, 456 claims (91.9%) had post-ACLR physiotherapy treatments, with the average number of treatments being 12 ± 8 (range 1-54) (Figure 2.5). The average time between surgery and the last physiotherapy treatment was 161 ± 143 days.

Figure 2.4

Number of Physiotherapy treatments for Surgery group prior to ACLR surgery.

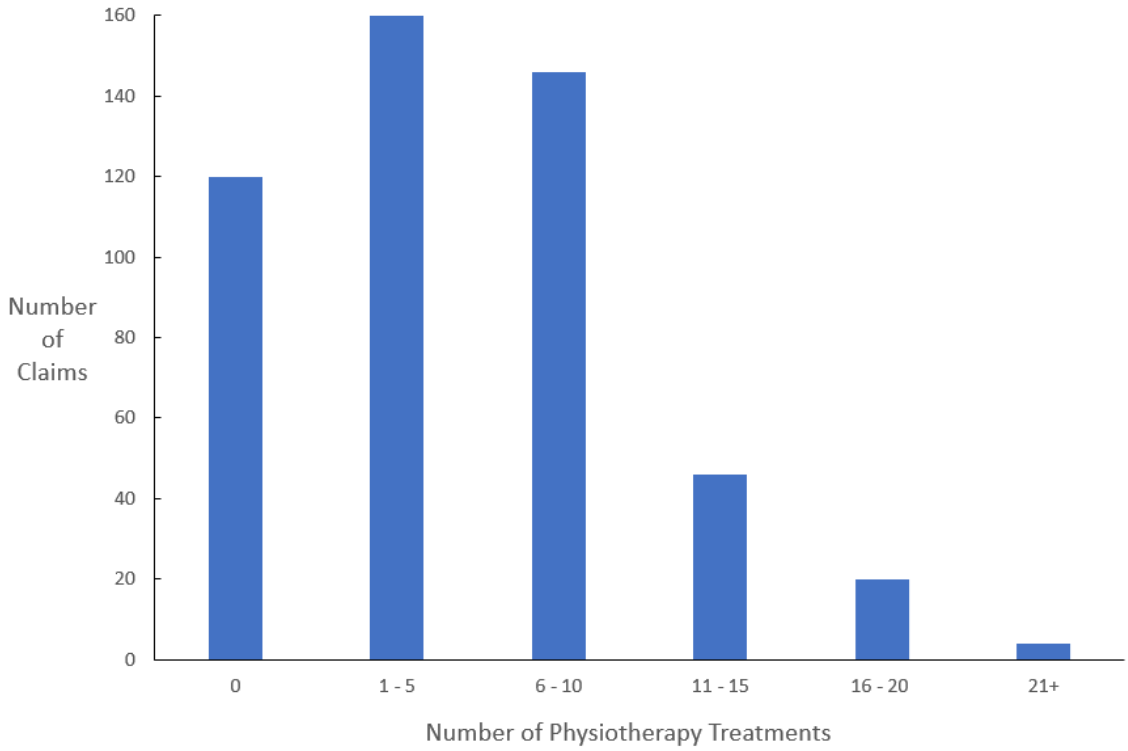
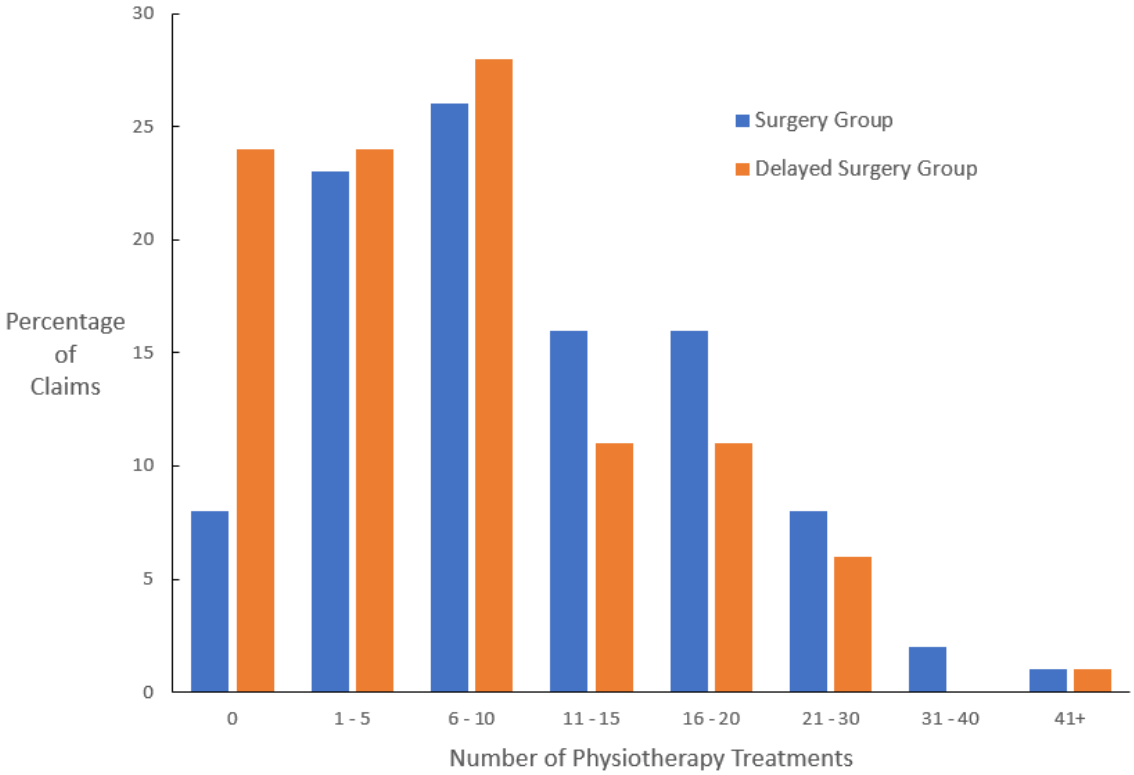


Figure 2.5

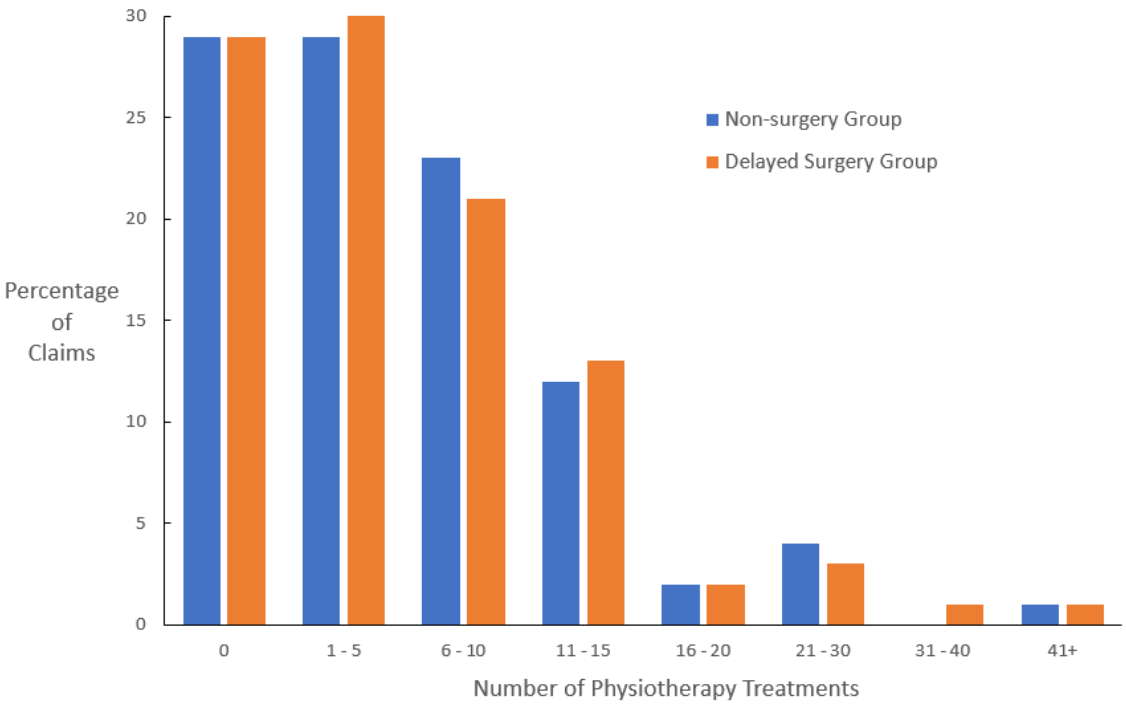
Number of Physiotherapy treatments per claim for the Surgery and Delayed surgery groups in the 12 months following ACLR surgery.



For the Delayed surgery group (n = 151), 109 claims (72.1%) had physiotherapy treatments in the 12 months following DOI, and the average number of treatments was 8 ± 8 (range 1-49) (Figure 2.6). In the 12 months following ACLR, 115 claims (76.1%) had physiotherapy treatments, with the average number of treatments being 10 ± 9 (range 1-59) (Figure 2.5). The average time between surgery and the last physiotherapy treatment was 143 ± 95 days.

Figure 2.6

Number of Physiotherapy treatments per claim for the Non-surgery and Delayed surgery groups in the 12 months following ACL injury.



For the Non-surgery group (n = 221), 157 claims (71.0%) had physiotherapy treatments in the 12 months following DOI, and the average number of treatments was 8 ± 6 (range 1-42) (Figure 2.6). The average time between DOI and the last physiotherapy treatment was 90 ± 84 days.

2.5.2 Earnings Related Compensation and Vocational Rehabilitation

For the Surgery group, 80 claims (16.1%) had earnings related compensation (ERC) paid in the 2 weeks prior to ACLR. Following surgery, 247 claims (49.8%) had ERC paid, for an average of 102 ± 93 days (range 3-809). In the 12 months after ACLR, 129 claims (26.0%) had approved VRS, with an average duration of 149 ± 100 days (range 3-809) of ERC paid. For claims with approved VRS, the average number of physiotherapy treatments in the 12 months following ACLR was 11 ± 8 (range 1-54). Of the 40 claims (8.0%) with no post-ACLR physiotherapy treatments, 9 had approved VRS, and the average number of ERC days paid on those claims was 181 ± 63.

For the Delayed surgery group, 9 claims (6%) had ERC paid in the 2 weeks prior to ACLR. Following surgery, 63 claims (41.7%) had ERC paid, for an average of 93 ± 104 days (range 11-611). In the 12 months after ACLR, 35 claims (23.1%) had approved VRS, with an average duration of 118 ± 122 days (range 27-611) ERC paid. For claims with approved VRS, the average number of physiotherapy treatments in the 12 months following ACLR was 11 ± 7 (range 2-29). Of the 36 claims (23.8%) with no post-ACLR physiotherapy treatments, 3 had approved VRS, with an average number of ERC days paid of 84.

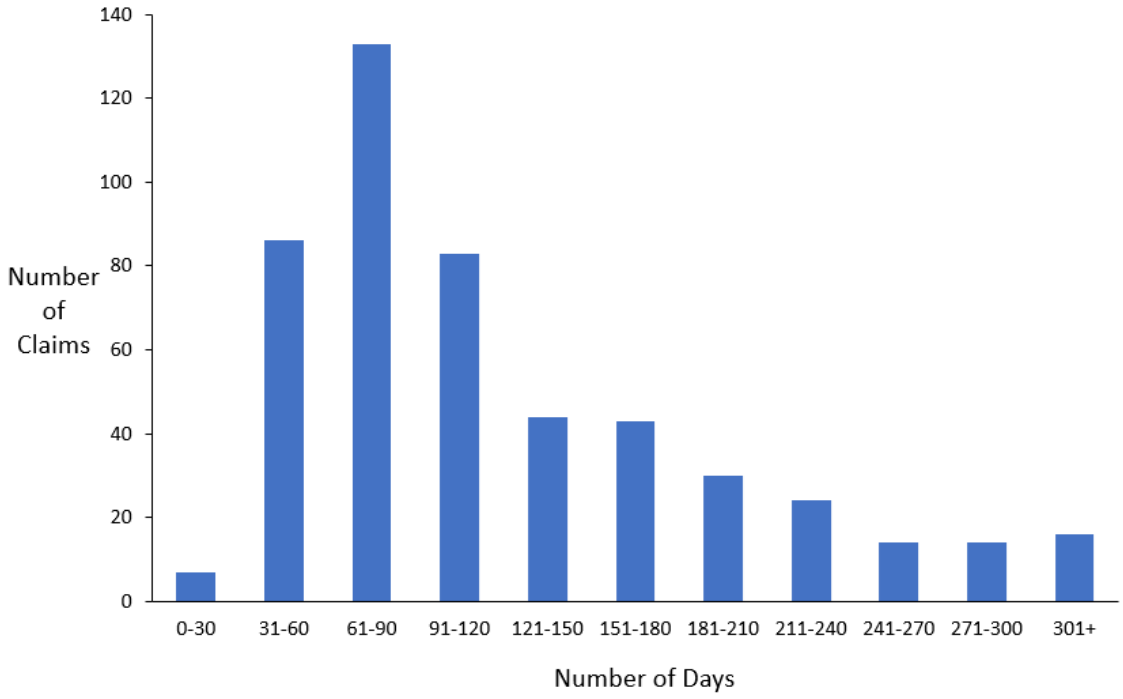
For the Non-surgery group, in the 12 months following injury, 9 claims (4.0%) had approved VRS, with an average of 147 ± 98 days (range 44-317) of ERC paid. For claims with approved VRS, the average number of physiotherapy treatments in the 12 months following DOI was 9 ± 7 (range 2-23). Of the 64 claims (28.9%) with no physiotherapy treatments in the 12 months following DOI, 2 had approved VRS, with an average number of ERC days paid of 173.

2.5.3 Days to Surgery

For the Surgery group, the average number of days between DOI and ACLR was 121 ± 74 (range 22-361), with 228 people (45.9%) undergoing ACLR within 90 days of injury and 397 people (80.0%) undergoing ACLR within 180 days of injury (Figure 2.7). For the Delayed surgery group, the average number of days between DOI and ACLR was 908 ± 565 (range 369-2939).

Figure 2.7

Number of days between ACL injury and ACLR for Surgery group.



2.5.4 Multiple ACL Injury

For all groups (n = 868), 95 people (10.9%) had suffered multiple ACL injuries. Across the Surgery and Delayed surgery groups (n = 647), 50 people (7.7%) suffered a subsequent ACL injury following ACLR – 33 (5.1%) ACL graft ruptures and 17 (2.6%) contralateral ACL injuries. The average number of days between ACLR and subsequent ACL injury was 617 ± 371 and 1210 ± 855 for the Surgery and Delayed surgery groups respectively. For both groups, 28 people (4.3%) had suffered a previous contralateral ACL injury and 3 people had suffered a previous ipsilateral ACL injury.

For the Non-surgery group, 1 person suffered a contralateral ACL injury 392 days after the initial ACL injury; 11 people had suffered a previous contralateral ACL injury, 8 of which had undergone ACLR, with 2 suffering subsequent ACL graft rupture.

2.6 Discussion

The aim of this study was to present a retrospective descriptive analysis of ACC claim data to gain insights into the duration and quantity of physiotherapy treatment following ACL injury in NZ.

Sporting and recreational activities accounted for the majority of ACL injuries, with popular change-of-direction activities in NZ (netball, rugby, soccer, touch) responsible for the greatest number of sporting ACL injuries, which is similar to previous findings (Gianotti et al., 2009; New Zealand ACL Registry, 2018). Nearly three quarters of all ACL injuries in the current study involved a non-contact mechanism of injury, which is consistent with previous reports of 72% (Boden et al., 2000).

2.6.1 Duration of Physiotherapy

Our results suggest people in NZ are not receiving physiotherapy treatment for an appropriate duration following ACL injury or surgery. Post-ACLR rehabilitation lasting up to 12 months is associated with improved knee flexor/extensor strength (Ageberg et al., 2008; Heijne & Werner, 2007; Risberg & Holm, 2009), greater performance during functional testing (Ebert et al., 2018), a greater rate of returning to pre-injury activities (Ardern et al., 2014; Della Villa et al., 2012; Edwards et al., 2018; Han et al., 2015; Rosso et al., 2018), and decreased re-injury risk (Grindem et al., 2016). Traditional progressions through ACL rehabilitation have been time-based, which can result in sub-optimal outcomes, as time after ACLR is not necessarily related to functional performance (Myer et al., 2012). Although post-surgical rehabilitation is recommend to last 9-12 months (van Melick et al., 2016), criterion-based measures of functional performance, incorporated within a biopsychosocial framework, are also recommended to determine rehabilitation progress (Dingenen & Gokeler, 2017; Larsen et al., 2015; Myer et al., 2006).

2.6.2 Quantity of Physiotherapy

Our results have highlighted a potential under-utilisation of physiotherapy treatment following ACL injury and surgery, and prior to ACL surgery, in NZ. Physiotherapists consider pre-operative rehabilitation to have an important influence on post-operative outcomes (Ebert et al., 2019). A structured physiotherapy-led pre-operative

rehabilitation programme of up to 27 sessions has been shown to be effective, safe, and improve outcomes two years after ACLR (Alshewaier et al., 2017; Eitzen et al., 2010; Eitzen et al., 2009; Failla et al., 2016; Logerstedt et al., 2013). We have shown 24% of people did not receive physiotherapy treatment prior to ACL surgery, which suggests the post-operative outcomes for almost one quarter of people in our sample may have been sub-optimal.

While many factors potentially influence outcomes after ACL injury and surgery, rehabilitation remains an important variable (Ebert et al., 2019), and is almost universally recommended (Adams et al., 2012; Lobb et al., 2012; van Melick et al., 2016). Over 80% of Australian physiotherapists believe 6-12 treatments are required in the first 6 weeks after ACL surgery (Ebert et al., 2019), with a physiotherapist review every two weeks recommended (Filbay & Grindem, 2019). Therefore, rehabilitation lasting 9-12 months would equate to between 21-35 physiotherapy visits within 12 months following ACL surgery. It appears people in the current study received considerably less physiotherapy treatment than evidence-based guidelines suggest, the reasons for which require further evaluation.

There are multiple barriers to people engaging in a healthcare service, which includes physiotherapy following ACL injury/surgery (Carrillo et al., 2011). Patient-specific barriers include health literacy/understanding of the condition, cultural beliefs, and socio-economic status; provider-specific barriers include clinician skills/knowledge and patient interactions; healthcare system barriers include cost, accessibility/waiting times, location of services, and the involvement of multiple providers (Bath et al., 2016; Douthit et al., 2015; Scheppers et al., 2006). In NZ, barriers to engaging with primary health care services include location, cost, suitability, and awareness of services (Ministry of Health, 2001). Strategies to overcome these barriers include encouraging early, appropriate intervention within a patients locale, ensuring cost effective services within an accountable healthcare system, and empowering people by improving health literacy through quality education (Ministry of Health, 2016).

The cost of private physiotherapy services may influence physiotherapy utilisation (Ebert et al., 2019). ACL rehabilitation in NZ is commonly supplied by private physiotherapy providers, who may charge a co-payment of up to $50 per treatment.

Although physiotherapy is available via the public health system at no cost, the vast majority of people seek physiotherapy from private providers (ACC, 2018b), who make up almost 70% of NZ's physiotherapy workforce (Physiotherapy New Zealand, 2018). Although there are a small number of private physiotherapists in NZ who do not charge a co-payment, unless the person is receiving VRS from ACC, they will likely have to contribute to the cost of their physiotherapy treatment or rehabilitation services. As such, socio-economic status can be a barrier to utilisation of physiotherapy services.

A lack of endorsement of rehabilitation by the Orthopaedic surgeon may have influenced physiotherapy treatment numbers in this study. Almost 40% of Orthopaedic surgeons in Australia do not consider pre-ACLR rehabilitation necessary and a small percentage even consider post-ACLR rehabilitation unnecessary (Ebert et al., 2019). While the surgeon is responsible for the surgery, the physiotherapist should lead the decision-making in rehabilitation (van Melick et al., 2016). Good communication between the surgeon and physiotherapist is essential following ACL injury (Grindem, Arundale, et al., 2018), to overcome any potential disconnect between providers (von Aesch et al., 2016).

ACL rehabilitation is described as time consuming, boring, and unable to provide sufficient results within a reasonable timeframe (Thorstensson et al., 2009), which likely contributes to decreased compliance to rehabilitation exercises following ACLR (Risberg et al., 2016). Poor adherence to treatment may influence physiotherapy utilisation and have a significant impact on clinical outcomes (Pizzari et al., 2002; Vermeire et al., 2001). Early physiotherapeutic intervention after ACL injury, including education on the importance of rehabilitation, can positively influence the patient experience and may increase adherence to rehabilitation (Grindem, Risberg, et al., 2015; Risberg et al., 2016; Scott et al., 2018). Increased adherence to rehabilitation is positively associated with functional ability following ACLR (Brewer et al., 2000; Pizzari et al., 2005; Rosso et al., 2018).

Patients may not be adequately informed of the rehabilitation requirements after ACL surgery (Cailliez et al., 2012). Decreased patient understanding of the importance of rehabilitation can negatively influence patient motivation (Grindem, Risberg, et al., 2015). Patient have high expectations regarding functional outcome after primary ACL

surgery (Webster & Feller, 2019). Although patient expectations align closely with the surgeons (Khair et al., 2018), the reality is these expectations are frequently not met (Ardern et al., 2014). A lack of patient education regarding the rehabilitation requirements may contribute to the unrealistic patient expectations regarding outcomes of ACL surgery (Feucht et al., 2016; Heijne et al., 2008). An effective clinician–patient relationship incorporating education on the requirements and importance of rehabilitation may improve patient motivation and adherence, increasing physiotherapy utilisation and the likelihood of an optimal outcome (Scott et al., 2018).

Although the number of ACC-funded physiotherapy treatments under a claim may give an indication of the amount of rehabilitation the person received, it cannot be assumed this accurately reflects the persons total rehabilitation. Other potential sources of rehabilitation include the Orthopaedic surgeon or other allied health professionals (Ebert et al., 2019), ACC-funded rehabilitation under VRS, non-clinically led rehabilitation (fitness trainer, gym instructor), privately funded physiotherapy, or self-directed rehabilitation. Our results showed for claims with approved VRS in the 12 months following ACL injury or surgery, the average number of physiotherapy treatments was very similar to claims without approved VRS, which indicates VRS had a negligible impact on the number of physiotherapy treatments per claim.

There is no clear evidence supervised rehabilitation after ACL surgery results in superior outcomes compared to minimally supervised rehabilitation (Anderson et al., 2016; Lobb et al., 2012), which may have contributed to low physiotherapy treatment numbers in the current study. Selected groups of patients, including young, athletic people, may achieve acceptable outcomes after ACL surgery with a minimally supervised rehabilitation programme involving less than 10 physiotherapy treatments over 3-12 months (Feller et al., 2004; Grant & Mohtadi, 2010; Hohmann et al., 2011).

Our results show over 70% of people in NZ engage in physiotherapy treatment after ACL injury, and over 90% engage in physiotherapy after ACL surgery. Ebert and Edwards et al. (2018) reported 91% of people engaged in supervised rehabilitation/physiotherapy after ACL surgery, but 45% of people reported rehabilitation following surgery lasted 3 months or less. Therefore, the majority of

people are initially receiving physiotherapy treatment following ACL injury or surgery, but our results suggest people do not remain engaged in rehabilitation for an appropriate duration.

Although our results suggest possible underutilisation of physiotherapy led services in the 12 months following ACL injury, an absence of outcome data means the relationship between utility and outcome is currently unknown. The NZ ACL Registry reports outcome data for people undergoing ACLR (New Zealand ACL Registry, 2018), but as details regarding the type, amount, or duration of rehabilitation received prior to or following surgery are unknown, it is not possible to correlate these outcomes with rehabilitation parameters. Although outcomes following ACLR may appear to be influenced by post-operative rehabilitation (Ebert et al., 2018; Edwards et al., 2018), this data was collected retrospectively, with participants subjectively grading the amount, type, and duration of rehabilitation they received. As details of the post-ACLR rehabilitation were not prospectively quantified, it is possible the subjects grading of their rehabilitation was not an accurate reflection of the actual rehabilitation received.

2.6.3 Days to Surgery

Almost half of the Surgery group proceeded to ACLR within 90 days of injury, and 80% within 180 days of injury. There is no accepted definition for early or delayed ACLR (Beynnon, Johnson, et al., 2005), with 'early' defined as between 2 days and 7 months of DOI, and 'delayed' as between 3 weeks and 24 years (Anderson et al., 2016). There are equivocal differences in outcomes between patients undergoing early verses delayed ACLR (Anderson et al., 2016; Eriksson et al., 2018; Lee et al., 2018; Smith et al., 2014; Wittenberg et al., 1998), although early surgical intervention may reduce the risk of subsequent meniscal or chondral injury, both of which are associated with worse outcomes following ACLR (Cinque et al., 2018; Cox et al., 2014).

Early ACLR is common practice, both domestically (New Zealand ACL Registry, 2018) and internationally (Delay et al., 2001; Sanders, Maradit, Bryan, Larson, et al., 2016). However, it can take at least six months following ACL injury for the true functional disability to be defined (Noyes et al., 1983). A significant number of patients who may initially appear unable to cope with an ACL injury are able to cope following six months of rehabilitation (Moksnes et al., 2008). The time interval from ACL injury to ACLR may

be less important as the condition of the knee at the time of surgery (Lattermann et al., 2018). Better pre-operative knee function is associated with less post-surgical complications and greater post-operative knee function (Beynnon, Johnson, et al., 2005; Filbay et al., 2017; Risberg et al., 2016). Therefore, treatment following ACL injury should involve physical rehabilitation to optimise functional ability before any decisions regarding surgical intervention are made (Eitzen et al., 2010; Thoma et al., 2019).

2.6.4 Multiple ACL Injury

Across all three groups, 11% of people had suffered multiple ACL injuries, which is slightly less than the overall rate for all ages (Wiggins et al., 2016). Younger people have a significantly higher rate of subsequent ACL injury after ACLR (Webster & Feller, 2016). Five percent of all people had suffered a previous ACL injury, and 2% went on to suffer a subsequent contralateral ACL injury. Following ACLR, graft rupture occurred in 5% of people, which is consistent with previously reported graft rupture rates (Crawford et al., 2013; Lai et al., 2018; van Yperen et al., 2018; Wright et al., 2011).

2.6.5 Limitations

No outcomes measures were collected for any clients, as this was not the purpose of the study, which limits the conclusions regarding the adequacy of the physiotherapy treatment received. No attempt was made to make any between group comparisons or to make any associations between variables, as without outcome data, these analyses would not offer any additional insights.

2.7 Conclusions

ACL injuries are a common injury in NZ, with ACC the primary funder of treatment for the condition. Rehabilitation following ACL injury can influence short and long-term outcomes. Our results indicate the number of ACC-funded physiotherapy sessions and duration over time following ACL injury is highly variable. Possible reasons for this variability include financial barriers, a lack of patient understanding, a lack of endorsement of rehabilitation by the surgeon, and the structure of the NZ healthcare system. No clinical or functional outcome data was collected in the current study, which limits the conclusions that can be drawn. However, when compared with

previous research, our results indicate people in NZ may not be accessing sufficient physiotherapy treatment following ACL injury. Future research should utilise validated measures to clarify outcomes from ACL injury in NZ. The use of such measures will allow for investigation into associations between patient outcomes and multiple variables along the ACL injury management pathway.

Chapter 3

The Relationship Between the Quantity and Duration of Post-operative Physiotherapy Treatment and Patient Outcomes Following Primary Anterior Cruciate Ligament Reconstruction: A Systematic Review

This chapter comprises the following manuscript:

Fausett, W., Reid, D., & Larmer, P. (2023). The relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following primary anterior cruciate ligament reconstruction: A systematic review. *Physical Therapy Reviews*, *28(*2). 111-134, doi:10.1080/10833196.2023.2195213

To maintain consistency of style throughout the thesis, the manuscript is presented here in a format that differs slightly to the published article (Appendix B).

3.1 Preface

Chapter two highlighted the low dosage of physiotherapy treatment received by ACL-injured people in NZ, irrespective of whether the injury is managed conservatively or surgically. Previous research has investigated the effects of the level of supervision during ACLR rehabilitation on patient outcomes, with a clear relationship between the two variables unable to be established. However, the effects of the quantity and duration of physiotherapy treatment on patient outcomes following ACLR is currently unknown, as that question has received little direct scrutiny to date. Therefore, the aim of the study in this chapter is to review the literature to determine if a relationship between the quantity and duration of physiotherapy treatment and patient outcomes following ACLR can be established.

3.2 Abstract

Background: Functional rehabilitation following anterior cruciate ligament reconstruction (ACLR) is often physiotherapist-led, and generally required to achieve patient goals. The quantity and duration of physiotherapist-led following could therefore potentially influence outcomes following ACLR, although the nature of this relationship is not clear.

Objective: To clarify the relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following ACLR.

Methods: A search of the PubMed/MEDLINE, Google Scholar, Cochrane Library, and EBSCO databases was made from inception to March 2021 to identify relevant studies. Key characteristics of the selected studies were extracted, with methodological quality evaluated using a modified version of the Downs and Black appraisal tool.

Results: The search strategy identified 1137 studies, 15 of which met inclusion criteria. Two studies were rated strong methodological quality, eight were rated moderate, and five were rated limited. Results across all 15 studies provided conflicting evidence regarding the effects of the quantity and duration of physiotherapy treatment on patient outcomes following ACLR.

Conclusions: Based on evidence of variable methodological quality, a clear relationship between the quantity and duration of physiotherapy treatment and patient outcomes following ACLR could not be established. Several themes were identified to guide future research in this area, including ensuring participant homogeneity, monitoring participant adherence to unsupervised rehabilitation, and utilising rehabilitation interventions that replicate everyday physiotherapy practice.

3.3 Introduction

An anterior cruciate ligament (ACL) rupture is a devastating injury leading to a loss of structural knee stability and reduced functional ability in the short term, and decreased activity levels and an increased risk of knee osteoarthritis in the long-term (Beynnon, Johnson, et al., 2005; Lindanger et al., 2019; Suter et al., 2017). The optimal management of an ACL rupture remains elusive, with multiple factors influencing

whether the injury is managed conservatively or surgically (Renström, 2013). ACL reconstruction (ACLR) is often considered necessary to reduce subsequent episodes of knee instability, permit a return to pre-injury activities, and preserve long-term knee joint health (Ardern et al., 2014; Marx et al., 2003; Sanders, Kremers, et al., 2016). Despite increased knowledge of how to prevent ACL injuries (Webster & Hewett, 2018), acceptable outcomes with conservative management (Frobell et al., 2013), and a high incidence of subsequent ACL injury after ACLR (Wiggins et al., 2016), rates of ACLR have increased significantly in recent years (Abram et al., 2020; Sutherland et al., 2019; Zbrojkiewicz et al., 2018).

Multiple factors can influence patient outcomes following ACLR, including, but not limited to, age, gender, concomitant injury, time from injury to surgery, and post-injury/ACLR rehabilitation (Cristiani, Mikkelsen, et al., 2020; Ebert et al., 2018; Paterno et al., 2017; Senorski, Svantesson, Baldari, et al., 2019). Post-ACLR rehabilitation typically involves a significant functional component (Andrade et al., 2019), although may also include psychological and vocational elements (Ardern, Kvist, et al., 2016) (See section 2.5.2). The functional component typically includes exercises and activities to re-establish knee joint mobility, rebuild muscle strength, and optimise neuromuscular control (Andersson et al., 2009; Risberg et al., 2004), followed by a graduated return to pre-injury activities (Adams et al., 2012).

With evidence-based clinical knowledge in rehabilitation and exercise therapy (Clark, 2015), physiotherapists possess the requisite skills to lead the functional component of an ACLR rehabilitation programme (Filbay & Grindem, 2019; Zadro & Pappas, 2018). Following ACLR, the quantity and duration of physiotherapy treatment is associated with an increased rate of return to sport (Han et al., 2015; Rosso et al., 2018; Yabroudi et al., 2021), a decreased re-injury risk (Law et al., 2021), greater self-reported knee function (Miller et al., 2017), and better performance on functional and clinical tests (Ebert et al., 2018; Królikowska, Sikorski, et al., 2018a). Results are equivocal however, with studies also reporting the quantity and duration of post-ACLR physiotherapy treatment has no effect on knee strength (De Carlo & Sell, 1997), patient-reported outcomes (Feller et al., 2004), and re-injury rates (Vincent et al., 2017).

Numerous patient reported outcome measures (PROMs) have been developed to evaluate outcomes following knee injury (Collins et al., 2011), with over 50 related to the ACL deficient knee alone (Johnson & Smith, 2001). PROMs provide an objective measure of an individual's subjective perception in relation to their functional status (Dingenen & Gokeler, 2017; Haywood, 2006). The increasing use of PROMs to assess patient outcomes has realised the following benefits: increased patient-centred care, greater ability to establish treatment value, and improved patient outcomes (Kyte et al., 2015). Factors associated with superior patient reported outcomes following ACLR include younger age, male sex, not smoking, receiving a hamstring tendon autograft, and the absence of concomitant injuries (Senorski, Svantesson, Baldari, et al., 2019).

Although physiotherapist-led rehabilitation following ACLR can have a positive effect on patient outcomes (Grindem, Granan, et al., 2015), the optimal dosage of post-ACLR physiotherapy treatment is currently unknown (van Melick et al., 2016). It is also not clear how the quantity and duration of post-ACLR physiotherapy treatment influences patient outcomes (Walker et al., 2020). Therefore, the aim of this review is to determine the relationship between the quantity and duration of post-operative physiotherapy treatment and patient reported outcomes following primary ACLR.

3.4 Methods

3.4.1 Registration

This review was registered on 1/4/21 with the PROSPERO International Register for Systematic Reviews. The ID for this review is: CRD42021240112.

3.4.2 Information Sources

Following advice from an experienced university librarian, a literature search was undertaken by the primary investigator (WF) using electronic databases accessible via the Auckland University of Technology library. PubMed/MEDLINE, Google Scholar, Cochrane Library, Sportdiscus, AMED, and CINAHL were searched from inception to March 2021. Search terms used included: patient reported outcome measures, outcome, physiotherapy, "physical therapy", rehabilitation, ACL, "anterior cruciate ligament", "anterior cruciate ligament reconstruction", duration, quantity, supervis*, unsupervis*, "home based". Boolean operators were used to combine search terms

(Appendix I). Only full text studies published in English were selected. Reference lists of included studies were searched to identify any eligible studies that may have been missed during database searches.

3.4.3 Eligibility Criteria

The following inclusion criteria were applied to select primary research studies relevant to the aim of this review:

(1) Randomised controlled trials and non-randomised prospective cohort studies.
(2) Participants had undergone primary ACLR.
(3) Participants had received post-operative physiotherapy treatment.
(4) Validated outcome data recorded prior to, and at the conclusion of, post-ACLR rehabilitation.

Studies were excluded if they met one of the following criteria:

(1) Retrospective designs, single case studies, abstracts, and expert reviews.
(2) Participants underwent revision ACLR.
(3) The dosage of post-ACLR physiotherapy treatment could not be quantified.
(4) Participants were less than 18 years of age.
(5) Participants had significant concomitant knee injury e.g. multi-ligament rupture, fracture, joint dislocation.

3.4.4 Study Selection and Data Collection

Once databases searches were complete, all results were either included or excluded for review in accordance with the PRISMA study selection process for systematic reviews (Page et al., 2021). After duplicates were removed, titles and abstracts of remaining studies were screened for relevance by one reviewer (WF). The full texts of articles that appeared relevant to the aim of the review were retrieved and independently screened by two reviewers (WF and DR). with inclusion and exclusion criteria subsequently applied. Any discrepancies regarding study selection were resolved by consensus discussion, with involvement of a third researcher (PL) if required.

Data was extracted from the selected studies by the lead author (WF) and tabulated under the following headings: (1) study type, (2) participant demographics, (3) intervention, (4) control, (5) outcome measures, (6) results.

3.4.5 Risk of Bias Assessment

Included studies were independently analysed by two reviewers (WF and DR) using a modified Downs and Black checklist. Any discrepancies were resolved via collective scientific debate, which included a third reviewer if necessary (PL). The modified Downs and Black checklist consists of 27 questions, with a maximum possible score of 28 points. The lower the overall score, the lower the methodological quality of the study. There are 4 sections, which look at reporting (x/11), external validity (x/3), internal validity (bias) (x/7) and internal validity–confounding (selection bias) (x/6) of a study. The final question relates to the overall power of the study (x/1). As utilised in previous systematic reviews (Erdrich et al., 2020; McGowan et al., 2017), the last question was modified from the original version, which had a score out of five, to a score out of one, with one point being awarded if a calculation of the study's power was included. As per previous systematic reviews (Erdrich et al., 2020; McGowan et al., 2017), a quality index was calculated, with studies rated as having strong, moderate, limited, or poor methodological quality (Table 3.1).

Table 3.1

Quality index scores.

Total score modified Downs and Black checklist (/28)	Percentage of total score	Quality Index
21+	75%+	Strong
14–20	50–74%	Moderate
7–13	25–49%	Limited
<7	<25%	Poor

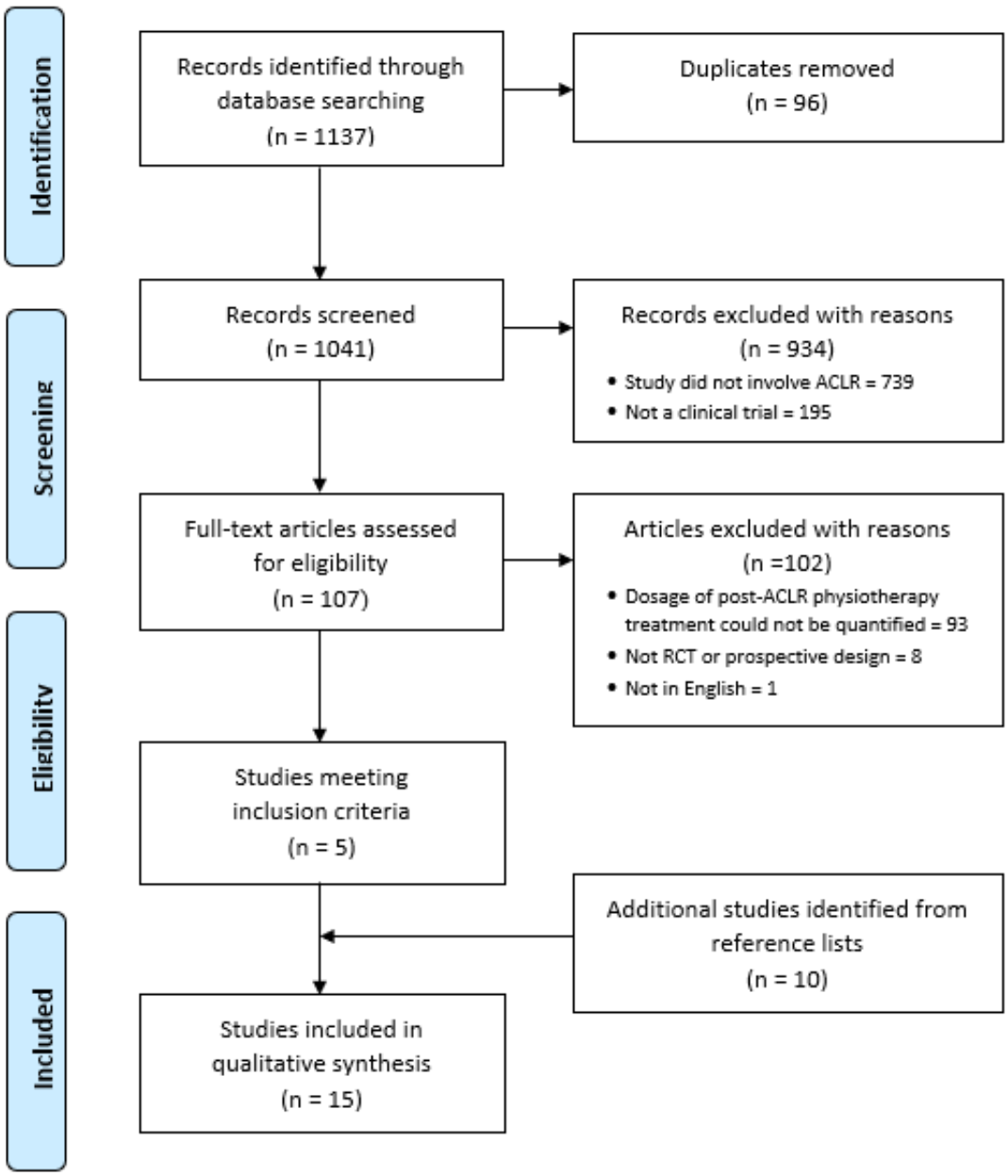
3.5 Results

3.5.1 Study Selection

The literature search identified 1137 records, with 15 studies meeting the inclusion criteria (Figure 3.1). Physiotherapy treatment data was then extracted from the 15 studies, which were divided into two groups – studies reporting the effects of the *Quantity* of post-ACLR physiotherapy treatment on patient outcomes (n = 11), and studies reporting the effects of the *Duration* of post-ACLR physiotherapy treatment on patient outcomes (n =4).

Figure 3.1

PRISMA flow diagram of study selection process.



3.5.2 Study Characteristics

The 11 *Quantity* studies consisted of nine randomised controlled trials (RCTs) and two prospective cohort studies (Table 3.2). The four *Duration* studies consisted of two RCTs and two prospective cohort studies (Table 3.3).

Table 3.2

Characteristics of selected studies reporting the effects of the quantity of physiotherapy treatment on patient outcomes following ACLR.

Author/ Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
(Schenck et al., 1997) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Average age of all subjects = 24 Subject activity level = Recreational athletes Time from ACL injury to ACLR = not stated Subjects: N = 37 (9 female) Clinic-based rehabilitation group N = 15 Home-based rehabilitation group N = 22	Clinic-based group Completed clinic-based functional rehabilitation Average number of PT treatments = 14 (range 6-40) Home-based group Completed an exercise-based functional program, monitored by a PT as required Average number of PT treatments = 3 (range 0-6)	None	1. Knee joint ROM 2. Knee joint laxity 3. Lysholm score 4. VAS pain scale 5. Sickness Impact Profile questionnaire 6. Single-leg hop for distance Average follow-up was 21.6 months (range 12 to 48 months)	No difference between Home-based rehabilitation versus Clinic-based rehabilitation for all outcomes	Total score x/28 = 8 Quality Index = 29% Quality Index Category = Limited
(Beard & Dodd, 1998) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Subject activity level = not stated Home-based rehabilitation group N = 13 (3 female) Average age at ACLR = 27 Average time from ACL injury to ACLR = 47 months Supervised rehabilitation group N = 13 (2 female)	All subjects completed same rehabilitation for first 4-6 weeks post-ACLR, then randomised to either Supervised or Home-based rehabilitation group Supervised group Performed an identical programme to the Home-based group, but also attended a supervised PT-led exercise class twice weekly.	None	1. IKDC score 2. Lysholm score 3. Tegner activity score 4. VAS for sports participation and activities of daily living 5. Isokinetic strength of the thigh muscles 6. Passive anterior sagittal translation of the knee joint Outcome measures recorded pre-ACLR, and 3- and 6-	No difference between Home-based rehabilitation versus Supervised rehabilitation for all outcomes	Total score x/28 = 20 Quality Index = 71% Quality Index Category = Moderate

	Average age at ACLR = 29 Average time from ACL injury to ACLR = 52 months	Median number of classes attended = 16 (range 10-22) out of a possible 32 Home-based group Performed rehabilitation exercises either at home or using commercial/private facilities. Attended the PT department for assessment, education, modification, and progression of rehabilitation programme		months post-ACLR		
(Fischer et al., 1998) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR. Time from ACL injury to ACLR for all subjects ranged from 1.5 to 216 months Subject activity level = not stated Home-based rehabilitation group N = 27 (11 female) Average age at ACLR = 32 Clinic-based rehabilitation group N = 27 (14 female) Average age at ACLR = 27	Home-based group Prescribed 6 PT treatments in the first 12 weeks post-ACLR – subjects averaged 5 (range 3-7) PT treatments Clinic-based group Subjects averaged 20 (range 10-28) PT treatment sessions	None	6/12/24 weeks Knee ROM Thigh girth Manual tests for knee stability Knee joint laxity 12/24 weeks Lysholm score 24 weeks Hop test battery (1 -leg hop for distance, timed 6-metre hop, triple hop for distance, triple slalom hop for distance) Health Status Questionnaire	No difference between Home-based rehabilitation versus Clinic-based rehabilitation for all outcomes	Total score x/28 = 17 Quality Index = 61% Quality Index Category = Moderate
(Grant et al., 2005) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Subject activity level = not stated Home based rehabilitation group	Home-based group Subjects averaged 3±1 (range 0-8) PT treatment sessions following ACLR Supervised group Subjects averaged 14±4	None	1. ACL-QOL questionnaire 2. Knee joint ROM 3. Knee joint ROM during walking 4. Knee joint laxity 5. Isokinetic quadriceps and hamstrings strength	Higher percentage of patients in Home-based rehabilitation group recorded acceptable knee joint ROM at 12-week follow up No difference between	Total score x/28 = 25 Quality Index = 89% Quality Index Category = Strong

	N = 73 (26 female) Average age at injury = 26 Average time from ACL injury to ACLR = 17 months Supervised rehabilitation group N = 72 (34 female) Average age at injury = 26 Average time from ACL injury to ACLR = 20 months	(range 2-20) PT treatment sessions following ACLR		All outcome measures recorded 6- and 12-weeks post-ACLR	Home-based rehabilitation versus Supervised rehabilitation for ROM during walking, joint laxity, and knee strength at 12-week follow-up	
(Ugutmen et al., 2008) Randomised controlled trial	All subjects underwent arthroscopic ACLR with hamstring graft Gender Male = 103 Female = 1 Average age of all subjects = 31.5 years Average time between ACL injury and ACLR for all subjects = 34.3 months (range 2-144 months) Subject activity level = not stated Home-based rehabilitation group N = 52 Clinic-based rehabilitation group N = 52	All subjects received weekly instruction on exercises for 6 weeks post-ACLR Home-based group Subjects seen 14 times by physiotherapists and the orthopaedic surgeon for physical examination and measurements Clinic-based group Number of PT treatments not stated	None	1. Hospital of Special Surgery score 2. IKDC score 3. Lysholm score 4. Thigh atrophy 5. Knee joint laxity 6. Knee joint ROM 7. Clinical tests for knee stability 8. VAS pain scale Average follow-up time = 31.1 months (range 12-66 months).	No difference between Home-based rehabilitation versus Clinic-based rehabilitation for all outcomes	Total score x/28 = 10 Quality Index = 36% Quality Index Category = Limited
(Revenäs et al., 2009) Randomised controlled trial	Subjects underwent arthroscopic bone-patella tendon-bone or hamstring tendon ACLR Guided Therapy group N = 27 (11 female)	Guided Therapy group Individual rehabilitation programme at least 2 x weekly, from 7-24 weeks post-ACLR, with PT review as required	None	1. IKDC score 2. Lysholm score 3. Tegner activity score 4. Isometric quadriceps strength 5. Single leg hop for	Guided Therapy rehabilitation group reported higher Lysholm score at 6-month follow-up Guided Therapy rehabilitation	Total score x/28 = 20 Quality Index = 71% Quality Index Category = Moderate

	Average age = 24 (16-40) Subjects with pre-injury Tegner score 9-10 = 52% Average time from ACL injury to ACLR = 22 months (range 4-177) Knee Class group N = 24 (7 female) Average age = 21 (16-39) Subjects with pre-injury Tegner score 9-10 = 67% Average time from ACL injury to ACLR = 9 months (range 3-44)	Median number of PT visits = 3 (range 0-8) Knee Class group Individual rehabilitation programme at least 2 x weekly, plus PT-led Knee Class 2 x weekly from 7-24 weeks post-ACLR Median number of Knee Class visits = 15 (range 13-36)		distance 6. Knee joint ROM Outcome measures recorded 6- and 12-months post-ACLR	group reported greater increase in Lysholm score at 12-month follow-up Knee Class rehabilitation group reported higher Tegner activity score at 12-month follow-up Non-compliant subjects in Knee Class rehabilitation group reported greater change in Lysholm score than compliant subjects	
(Grant & Mohtadi, 2010) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Subject activity level = not stated Home based rehabilitation group N = 40 (13 female) Average age at injury = 26 Average time from ACL injury to ACLR = 17 months Supervised rehabilitation group N = 48 (25 female) Average age at injury = 26 Average time from ACL injury to ACLR = 20 months	Home-based group Subjects averaged 3±1 (range 0-8) PT treatment sessions following ACLR Supervised group Subjects averaged 14±4 (range 2-20) PT treatment sessions following ACLR	None	1. ACL-QOL questionnaire 2. IKDC score 3. Knee joint ROM 4. Knee joint laxity 5. Isokinetic quadriceps and hamstrings strength Outcome measures recorded at an average of 38 months (range 26-52) post-ACLR	Home-based rehabilitation group reported significantly higher ACL-QOL scores No difference between Home-based rehabilitation versus Supervised rehabilitation for IKDC score, ROM, joint laxity, or quadriceps and hamstrings strength	Total score x/28 = 26 Quality Index = 93% Quality Index Category = Strong
(Hohmann et al., 2011) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Subject activity level = “physically active”	Supervised group Prescribed 18 PT sessions following ACLR Home-based group Subjects given handout with	None	1. Lysholm score 2. Tegner activity score 3. Isokinetic quadriceps and hamstring strength 4. Hop test battery (single hop for distance, timed	Home-based rehabilitation group recorded greater isometric knee extensor strength at 3-month follow-up	Total score x/28 = 19 Quality Index = 68% Quality Index Category = Moderate

	Supervised rehabilitation group N = 20 (4 female) Average age at injury = 28 Average time from ACL injury to ACLR = <3 months Home based rehabilitation group N = 20 (6 female) Average age at injury = 27 Average time from ACL injury to ACLR = <3 months	rehabilitation protocol following ACLR, with no PT sessions prescribed.		hop and vertical jump) All outcome measures recorded pre-ACLR, then 3-, 6-, 9-, and 12-months post-ACLR	Supervised rehabilitation group recorded greater isokinetic knee extensor strength at 6-month follow-up No difference between Home-based rehabilitation versus Supervised rehabilitation for Lysholm score, Tegner activity score, and hop test battery.	
(Lim et al., 2019) Randomised controlled trial	All subjects underwent arthroscopic ACLR with hamstring graft Subject activity level = not stated Supervised rehabilitation group N = 15 (5 female) Average age = 32 Average time from ACL injury to ACLR = >3 months Home based rehabilitation group N = 15 (6 female) Average age = 39 Average time from ACL injury to ACLR = >3 months	Supervised group Prescribed 44 PT-supervised rehabilitation sessions post-ACLR. No home-based exercises performed Home-based group Advised to complete rehabilitation exercises twice per week following ACLR. Weekly follow-up with physiotherapist via phone	None	1. Isokinetic quadriceps and hamstring strength 2. Proprioception (Biodex Stability System) Outcome measures recorded pre-ACLR and 24 weeks post-ACLR	No difference between Home-based rehabilitation versus Supervised rehabilitation for quadriceps and hamstring strength Supervised rehabilitation group recorded increase in proprioception	Total score x/28 = 18 Quality Index = 64% Quality Index Category = Moderate
(Przybylak et al., 2019) Prospective cohort – non-randomised	Hamstring tendon ACLR N = 39 Bone-patella tendon-bone ACLR N = 11 Subject activity level = Amateur recreational athletes Supervised rehabilitation group N = 25 (7 female)	Supervised group Prescribed 46 PT-supervised rehabilitation sessions following ACLR Home-based group Prescribed 5 PT-supervised rehabilitation sessions following ACLR	None	1. Kujala Anterior Knee Pain Questionnaire 2. Tegner activity score 3. KOOS 4. Knee joint ROM 5. Functional Movement Screen Outcome measures recorded pre-ACLR and 12-months	Supervised rehabilitation group reported greater increases in the KOOS Symptoms, QoL, and Sport subscales, Tegner score, and Functional Movement Screen score	Total score x/28 = 13 Quality Index = 46% Quality Index Category = Limited

	Average age = 34 Average time from ACL injury to ACLR = >6 months Home-based rehabilitation group N = 25 (6 female) Average age = 27 Average time from ACL injury to ACLR = >6 months			post-ACLR		
(Rhim et al., 2021) Prospective cohort – non-randomised	All subjects underwent arthroscopic ACLR with hamstring graft Subject activity level = not stated Time from ACL injury to ACLR = not stated Supervised rehabilitation group N = 13 (3 female) Average age = 27 years Home-based rehabilitation group N = 13 (4 female) Average age = 29 years	Supervised group Subjects received 12 PT treatments in the first 12 weeks post-ACLR, then bi-weekly treatments at the discretion at the PT for an unspecified duration Home-based group Subjects received instruction on post-ACLR rehabilitation exercises as an in-patient, and then underwent PT review at 2, 6, 12, and 24 weeks post-ACLR	None	1. Isokinetic quadriceps and hamstring strength 2. Dynamic postural stability (Biodex Stability System) 3. Lysholm score All outcome measures recorded pre-ACLR, and 6- and 12-months post-ACLR	Supervised rehabilitation group recorded greater hamstring strength at 12-month follow-up Supervised rehabilitation group demonstrated greater postural stability at 6- and 12-month follow-up Supervised rehabilitation group reported higher Lysholm scores at 12-month follow-up	Total score x/28 = 17 Quality Index = 61% Quality Index Category = Moderate

Abbreviations: ACL = anterior cruciate ligament; ACLR = anterior cruciate ligament reconstruction; VAS = visual analogue scale; IKDC = International Knee Documentation Committee; PT = physiotherapy/physiotherapist; KOOS = Knee Injury and Osteoarthritis Outcome Score; ROM = range of motion; QOL = quality of life; VAS = visual analogue scale.

Table 3.3

Characteristics of selected studies reporting the effects of the duration of physiotherapy treatment on patient outcomes following ACLR.

Author/ Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
(Beynnon, Uh, et al., 2005) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR. Subject activity level = Moderately active (Pre-injury Tegner score = ≥5) Accelerated rehabilitation group N = 10 (5 female) Average age at ACLR = 30 Average time from ACL injury to ACLR = 91 days Non-accelerated rehabilitation group N = 12 (6 female) Average age at ACLR = 35 Average time from ACL injury to ACLR = 124 days	Both groups attended supervised rehabilitation sessions with a PT 3x/week and performed home exercises on other days Both rehabilitation programmes included the same exercises/activities Accelerated group Post-ACLR rehabilitation lasted 19 weeks Non-accelerated group Post-ACLR rehabilitation lasted 32 weeks	None	1. IKDC score 2. KOOS 3. Tegner activity score 4. Knee joint laxity 5. Single leg hop for distance Outcome measures recorded at 3-, 6-, 12- and 24-months post-ACLR	No difference between Accelerated rehabilitation versus Non-accelerated rehabilitation for all outcomes	Total score x/28 = 19 Quality Index = 68% Quality Index Category = Moderate
(Beynnon et al., 2011) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR. Subject activity level = not stated Accelerated rehabilitation group N = 19 (6 female) Average age at ACLR = 30 Average time from ACL injury to ACLR = 56 days Non-accelerated rehabilitation group N = 17 (8 female) Average age at ACLR = 30 Average time from ACL injury to ACLR =	Both groups attended supervised rehabilitation sessions with a PT 3x/week and performed home exercises on other days. Both groups competed the same volume of post-ACLR rehabilitation Accelerated group Post-ACLR rehabilitation lasted 19 weeks Non-accelerated group Post-ACLR rehabilitation lasted 32 weeks	None	1. IKDC score 2. KOOS 3. Tegner activity score 4. Knee joint laxity 5. Single leg hop for distance 6. Isokinetic quadriceps and hamstrings strength 7. Proprioception Outcome measures recorded pre-ACLR,	Accelerated rehabilitation group recorded greater quadriceps strength at 3-month follow-up No difference between Accelerated rehabilitation versus Non-accelerated rehabilitation for all other outcomes	Total score x/28 = 20 Quality Index = 71% Quality Index Category = Moderate

	66 days			then at 3-, 6-, 12- and 24-months post-ACLR		
(Królikowska, Czamara, Szuba, et al., 2018) Prospective cohort – non-randomised	All subjects in Groups 1 and 2 underwent arthroscopic ACLR with hamstring graft Subject activity level = not stated Group 1 N = 20 (0 female) Average age = 26 Average time from ACL injury to ACLR = not reported Group 2 N = 15 (0 female) Average age = 27 Average time from ACL injury to ACLR = not reported Group 3 N = 20 (0 female) Average age = 23 No known orthopaedic problems	Group 1 Average of 28 weeks PT-supervised rehabilitation post-ACLR Group 2 Average of 11 weeks PT-supervised rehabilitation post-ACLR, then continued with home-based, unsupervised rehabilitation Compliance/adherence to home-based rehabilitation not recorded	Group 3 No rehabilitation	1. Vertical ground reaction force during one- and two-legged vertical jumps Group 1 Final evaluation at 28 weeks post-ACLR Group 2 Final evaluation at 32 weeks post-ACLR	Group 1 recorded greater limb symmetry during two-legged vertical jump compared to Group 2	Total score x/28 = 10 Quality Index = 36% Quality Index Category = Limited
(Królikowska, Sikorski, et al., 2018b) Prospective cohort – non-randomised	All subjects in Groups 1 and 2 underwent arthroscopic ACLR with hamstring graft Subject activity level = Pre-injury Tegner activity score >4 and <9 Group 1 N = 15 (0 female) Average age = 25 Average time from ACL injury to ACLR = 33 weeks Group 2 N = 15 (0 female)	Group 1 Average of 27 weeks of PT-supervised rehabilitation following ACLR Group 2 Average of 8 weeks of PT-supervised rehabilitation following ACLR, then continued with home-based, unsupervised rehabilitation Compliance/adherence to home-based rehabilitation not recorded	Group 3 No rehabilitation	1. IKDC score 2. Knee joint circumference 3. Thigh circumference 4. Knee joint ROM 5. VAS pain scale 6. Agility run test Group 1 Final evaluation 27 weeks post-ACLR Group 2	Group 2 recorded worse performance on agility run test than Groups 1 and 3 Duration of supervised rehabilitation significantly correlated with agility run test performance	Total score x/28 = 11 Quality Index = 39% Quality Index Category = Limited

	Average age = 28 Average time from ACL injury to ACLR = 33 weeks Group 3 N = 30 (0 female) Average age = 25 No known orthopaedic problems	Final evaluation 33 weeks post-ACLR

Abbreviations: ACL = anterior cruciate ligament; ACLR = anterior cruciate ligament reconstruction; VAS = visual analogue scale; IKDC = International Knee Documentation Committee; PT = physiotherapist; KOOS = Knee Injury and Osteoarthritis Outcome Score; ROM = range of motion.

3.5.3 Participants

For *Quantity* studies, participant numbers ranged from 26 (Beard & Dodd, 1998; Rhim et al., 2021) to 145 (Grant et al., 2005), with the total number of participants being 651 (30% female) (Table 3.2). The average age of participants across the 22 study groups was 28 years (range 21 – 39 years). Eight of 11 *Quantity* studies reported an average time between ACL injury and ACLR, which ranged from less than 12 weeks to 52 months, with one study reporting up to an 18-year interval between ACL injury and ACLR for some participants (Fischer et al., 1998).

For *Duration* studies, participant numbers ranged from 22 (Beynnon, Uh, et al., 2005) to 60 (Królikowska, Sikorski, et al., 2018b), with the total number of participants being 173 (14% female) (Table 3.3). The average age of participants across the 10 study groups was 28 years (range 23 – 35 years). The average time from ACL injury to ACLR ranged from 56 days to 33 weeks, with one study not reporting the time between ACL injury and ACLR (Królikowska, Czamara, Szuba, et al., 2018).

No *Quantity* study reported an objective measure of pre-injury activity level for participants. Two of four *Duration* studies reported a pre-injury activity level for participants, with Tegner Activity Scale score ranging from five to eight (Beynnon, Uh, et al., 2005; Królikowska, Sikorski, et al., 2018b).

3.5.4 Interventions

Rehabilitation interventions for the *Quantity* studies are summarised in Table 3.2. The average number of post-ACLR physiotherapy treatments for the lesser treatment groups was 3 (range 0-14). Four studies did not clearly report the duration of physiotherapy treatment for the lesser treatment group. The average number of post-ACLR physiotherapy treatments for the greater treatment groups was 21 (range 12-46).

Rehabilitation interventions for the *Duration* studies are summarised in Table 3.3. Post-ACLR physiotherapy treatment duration across all study groups ranged from 8-19 weeks for shorter duration groups and from 27-32 weeks for longer duration groups. In both studies by Beynnon and colleagues, where participants in the 19- and 32-week groups completed the same rehabilitation programme, the 19-week group completed the same volume of

rehabilitation in a shorter time (Beynnon et al., 2011; Beynnon, Uh, et al., 2005). In both studies by Królikowska and colleagues, participants in the shorter duration groups elected to discontinue physiotherapist-supervised rehabilitation but were advised to continue with home-based rehabilitation (Królikowska, Czamara, Szuba, et al., 2018; Królikowska, Sikorski, et al., 2018b).

3.5.5 Controls

None of the 11 *Quantity* studies included a control group, with all studies comparing results between groups of participants receiving different quantities of post-ACLR physiotherapy treatment (Table 3.2). Two *Duration* studies included a control group where participants had not undergone ACLR and received no rehabilitation, with two studies comparing results between groups of participants undergoing post-ACLR physiotherapy treatment of different durations (Table 3.3).

3.5.6 Methodological Quality

The methodological quality and Quality Index (% and categorisation) of the *Quantity* and *Duration* studies are presented in Table 3.4 and Table 3.5 respectively. For *Quantity* studies, the average quality score was 17/28 (range 8-26), with an average Quality Index of 63% (range 21-93%). Regarding methodological quality, two studies rated 'strong', six rated 'moderate', and three rated 'limited'. Scores ranged from 3-11/11 in the Reporting section, from 0-3/3 in the External Validity section, from 2-6/7 in the Internal Validity (Bias) section, and from 1-6/6 in the Internal Validity (Confounding) section. Only six of 11 *Quantity* studies reported a power analysis.

For *Duration* studies, the average score was 15/28 (range 10-20), with an average Quality Index of 53.5% (range 36-71%). Two studies rated 'moderate' methodological quality and two rated 'limited' methodological quality. Scores ranged from 8-10/11 in the Reporting section, from 0-1/3 in the External Validity section, from 3-5/7 in the Internal Validity (Bias) section, and from 2-6/6 in the Internal Validity (Confounding) section. Two of four *Duration* studies reported a power analysis.

Table 3.4

Modified Downs and Black scores for studies reporting the effect of the quantity of post-ACLR physiotherapy treatment on patient outcomes.

	Schenk et al (1997)	Beard & Dodd (1985)	Fischer et al (1998)	Grant et al 2005)	Ugutmen et al (2008)	Revenas et al (2009)	Grant et al (2010)	Hohmann et al (2011)	Lim et al (2019)	Przybylak et al (2019)	Rhim et al (2020)
Reporting											
1. Is the hypothesis/aim/objective of the study clearly described? (yes = 1, no = 0)	1	1	1	1	0	1	1	1	1	1	1
2. Are the main outcomes to be measured clearly described in the Introduction or Methods section? (yes = 1, no = 0)	1	1	1	1	1	1	1	1	1	1	1
3. Are the characteristics of the patients included in the study clearly described? (yes = 1, no = 0)	0	0	1	1	0	1	1	1	1	1	1
4. Are the interventions of interest clearly described? (yes = 1, no = 0)	1	1	1	1	0	1	1	1	1	1	1
5. Are the distributions of principal confounders in each group of subjects to be compared clearly described? (yes = 2, partially = 1, no = 0)	0	1	0	2	0	2	2	0	1	0	1
6. Are the main findings of the study clearly described? (yes = 1, no = 0)	1	1	1	1	1	1	1	1	1	1	1
7. Does the study provide estimates of the random variability in the data for the main outcomes? (yes = 1, no = 0)	0	1	1	1	0	0	1	1	1	1	1
8. Have all important adverse events that may be a consequence of the intervention been reported? (yes = 1, no = 0)	0	0	0	0	0	0	1	0	0	0	0
9. Have the characteristics of patients lost to follow-up been described? (yes = 1, no = 0)	0	0	1	1	1	1	1	1	1	0	0
10. Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001? (yes = 1, no = 0)	0	0	0	1	0	1	1	1	1	1	1
Reporting Score x/11	4	6	7	10	3	9	11	8	9	7	8
External validity											
11. Were the subjects asked to participate in	0	0	0	1	0	1	1	1	0	0	0

the study representative of the entire population from which they were recruited? (yes = 1, unable to determine = 0, no = 0)											
12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited? (yes = 1, unable to determine = 0, no = 0)	0	0	0	0	0	0	1	0	0	0	0
13. Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive? (yes = 1, unable to determine = 0, no = 0)	1	1	1	1	1	0	1	1	0	0	1
External Validity Score x/3	1	1	1	2	1	1	3	2	0	0	1
Internal validity - Bias											
14. Was an attempt made to blind study subjects to the intervention they have received? (yes = 1, unable to determine = 0, no = 0)	0	0	0	0	0	0	0	0	0	0	0
15. Was an attempt made to blind those measuring the main outcomes of the intervention? (yes = 1, unable to determine = 0, no = 0)	1	1	0	1	0	1	1	1	1	0	0
16. If any of the results of the study were based on “data dredging”, was this made clear? (yes = 1, unable to determine = 0, no = 0)	0	1	1	1	0	1	1	0	1	1	1
17. In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? (yes = 1, unable to determine = 0, no = 0)	0	1	1	1	0	1	0	1	1	1	1
18. Were the statistical tests used to assess the main outcomes appropriate? (yes = 1, unable to determine = 0, no = 0)	0	1	1	1	1	1	1	1	1	1	1
19. Was compliance with the intervention/s reliable? (yes = 1, unable to determine = 0, no = 0)	0	1	1	1	0	0	1	0	0	0	0
20. Were the main outcome measures used accurate (valid and reliable)? (yes = 1,	1	1	1	1	1	1	1	1	1	1	1

unable to determine = 0, no = 0)											
Internal Validity – Bias Score x/7	2	6	5	6	2	5	5	4	5	4	4
Internal validity – Confounding (selection bias)											
21. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population? (yes = 1, unable to determine = 0, no = 0)	0	1	1	1	1	1	1	1	0	0	1
22. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time? (yes = 1, unable to determine = 0, no = 0)	0	1	1	1	1	1	1	1	1	1	1
23. Were study subjects randomized to intervention groups? (yes = 1, unable to determine = 0, no = 0)	1	1	1	1	1	1	1	1	1	0	0
24. Was the randomized intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable? (yes = 1, unable to determine = 0, no = 0)	0	1	0	1	0	0	1	0	0	0	0
25. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn? (yes = 1, unable to determine = 0, no = 0)	0	1	0	1	0	0	1	0	1	1	1
26. Were losses of patients to follow-up taken into account? (yes = 1, unable to determine = 0, no = 0)	0	1	1	1	1	1	1	1	1	0	0
Internal Validity – Confounding Score x/6	1	6	4	6	4	4	6	4	4	2	3
Power											
27. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? (yes = 1, unable to determine = 0, no = 0)	0	1	0	1	0	1	1	1	0	0	1
Total score x/28	8	20	17	25	10	20	26	19	18	13	17
Quality Index	29%	71%	61%	89%	36%	71%	93%	68%	64%	46%	61%
Quality Index Category	Limited	Moderate	Moderate	Strong	Limited	Moderate	Strong	Moderate	Moderate	Limited	Moderate

Table 3.5

Modified Downs and Black scores for studies reporting the effect of the duration of post-ACLR physiotherapy on patient outcomes.

	Beynnon et al (2005)	Beynnon et al (2011)	Królikowska et al (2018a)	Królikowska et al (2018b)
Reporting				
1. Is the hypothesis/aim/objective of the study clearly described? (yes = 1, no = 0)	1	1	1	1
2. Are the main outcomes to be measured clearly described in the Introduction or Methods section? (yes = 1, no = 0)	1	1	1	1
3. Are the characteristics of the patients included in the study clearly described? (yes = 1, no = 0)	1	1	1	1
4. Are the interventions of interest clearly described? (yes = 1, no = 0)	1	1	1	1
5. Are the distributions of principal confounders in each group of subjects to be compared clearly described? (yes = 2, partially = 1, no = 0)	2	2	1	1
6. Are the main findings of the study clearly described? (yes = 1, no = 0)	1	1	1	1
7. Does the study provide estimates of the random variability in the data for the main outcomes? (yes = 1, no = 0)	1	1	1	1
8. Have all important adverse events that may be a consequence of the intervention been reported? (yes = 1, no = 0)	0	0	0	0
9. Have the characteristics of patients lost to follow-up been described? (yes = 1, no = 0)	1	1	0	0
10. Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001? (yes = 1, no = 0)	1	1	1	1
Reporting Score x/11	10	10	8	8
External Validity				
11. Were the subjects asked to participate in the study representative of the entire population from which they were recruited? (yes = 1, unable to determine = 0, no = 0)	1	1	0	0
12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited? (yes = 1, unable to determine = 0, no = 0)	0	0	0	0
13. Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive? (yes = 1, unable to determine = 0, no = 0)	0	0	0	0
External Validity Score x/3	1	1	0	0
Internal Validity - Bias				
14. Was an attempt made to blind study subjects to the intervention they have received? (yes = 1, unable to determine = 0, no = 0)	0	0	0	0
15. Was an attempt made to blind those measuring the main outcomes of the intervention? (yes = 1, unable to determine = 0, no = 0)	0	1	0	0
16. If any of the results of the study were based on “data dredging”, was this made clear? (yes = 1, unable to determine = 0, no = 0)	1	1	1	1
17. In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?	1	1	0	1

(yes = 1, unable to determine = 0, no = 0)				
18. Were the statistical tests used to assess the main outcomes appropriate? (yes = 1, unable to determine = 0, no = 0)	1	1	1	1
19. Was compliance with the intervention/s reliable? (yes = 1, unable to determine = 0, no = 0)	0	0	0	0
20. Were the main outcome measures used accurate (valid and reliable)? (yes = 1, unable to determine = 0, no = 0)	1	1	1	1
Internal Validity – Bias Score x/7	4	5	3	4
Internal validity – Confounding (selection bias)				
21. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population? (yes = 1, unable to determine = 0, no = 0)	1	1	1	1
22. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time? (yes = 1, unable to determine = 0, no = 0)	1	1	1	1
23. Were study subjects randomized to intervention groups? (yes = 1, unable to determine = 0, no = 0)	1	1	0	0
24. Was the randomized intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable? (yes = 1, unable to determine = 0, no = 0)	1	1	0	0
25. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn? (yes = 1, unable to determine = 0, no = 0)	1	1	0	0
26. Were losses of patients to follow-up taken into account? (yes = 1, unable to determine = 0, no = 0)	1	1	0	0
Internal Validity – Confounding Score x/6	6	6	2	2
Power				
27. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? (yes = 1, unable to determine = 0, no = 0)	1	1	0	0
Total score x/28	19	20	10	11
Quality Index	68%	71%	36%	39%
Quality index Category	Moderate	Moderate	Limited	Limited

3.5.7 Outcomes

A wide range of patient-reported, clinical, and functional outcome measures were used in the *Quantity* studies (Table 3.2). For patient-reported outcome measures, two studies reported a positive effect for a greater quantity of physiotherapy treatment (Przybylak et al., 2019; Rhim et al., 2021), one study reported a positive effect for a lesser quantity of treatment (Grant & Mohtadi, 2010), and one study reported a positive effect for both greater and lesser quantities of physiotherapy treatment (Revenäs et al., 2009). For clinical outcome measures, two studies reported a positive effect for a greater quantity of physiotherapy treatment (Lim et al., 2019; Rhim et al., 2021), one study reported a positive effect for less treatment (Grant et al., 2005), and one study reported a positive effect for both greater and lesser quantities of physiotherapy treatment (Hohmann et al., 2011). For functional outcome measures, two studies reported a positive effect for a greater quantity of physiotherapy treatment (Przybylak et al., 2019; Rhim et al., 2021). Four studies reported the quantity of post-ACLR physiotherapy treatment had no significant effect on any outcome measure (Beard & Dodd, 1998; Fischer et al., 1998; Schenck et al., 1997; Ugutmen et al., 2008). Average follow up periods across all *Quantity* study groups ranged from 12 weeks (Grant et al., 2005) to 38 months (Grant & Mohtadi, 2010).

A range of patient-reported, clinical, and functional outcome measures were also used in the *Duration* studies (Table 3.3). The duration of post-ACLR physiotherapy treatment had no effect on patient-reported outcome measures (IKDC, KOOS, Tegner score, VAS pain score). A longer duration of physiotherapy treatment had a positive effect on functional outcomes (vertical jump performance, agility run performance) (Królikowska, Czamara, Szuba, et al., 2018; Królikowska, Sikorski, et al., 2018b) and clinical outcomes (quadriceps strength, thigh circumference) (Beynnon et al., 2011; Królikowska, Sikorski, et al., 2018b). Follow up periods across all *Duration* study groups ranged from 27 weeks (Królikowska, Sikorski, et al., 2018b) to 24 months (Beynnon et al., 2011; Beynnon, Uh, et al., 2005).

3.5.8 Strength of Evidence

Meta-analysis was not possible due to the heterogeneity of the selected studies. A synthesis of the overall evidence was therefore performed using the criteria described in Table 3.6 (Van Tulder et al., 2003).

Table 3.6

Overall levels of evidence.

Level of Evidence	Requirement
Strong	Consistent findings among multiple high quality randomised controlled trials (RCTs)
Moderate	Consistent findings among multiple low quality RCTs and/or case-controlled trials (CCTs) and/or one high quality RCT
Limited	One low quality RCT and/or CCT
Conflicting	Inconsistent findings among multiple trials (RCTs and/or CCT)

For *Quantity* studies, the two studies rated 'strong' methodological quality reported a lesser quantity of post-ACLR physiotherapy treatment was positively associated with patient outcomes. Of the six studies rated 'moderate' methodological quality, two reported the quantity of post-ACLR physiotherapy treatment had no effect on patient outcomes, two reported the quantity of post-ACLR physiotherapy treatment had conflicting effects on patient outcomes, and two reported the quantity of post-ACLR physiotherapy treatment had a positive effect on patient outcomes. Of the three studies rated 'limited' methodological quality, one reported the quantity of post-ACLR physiotherapy treatment had a positive effect on patient outcomes, and two reported the quantity of post-ACLR physiotherapy treatment had no effect on patient outcomes. Overall, the level of evidence for the *Quantity* studies is best described as 'Conflicting' (Van Tulder et al., 2003).

For *Duration* studies, the two studies rated 'moderate' methodological quality reported the duration of post-ACLR physiotherapy treatment had no effect on patient outcomes. The two studies rated 'limited' methodological quality reported a longer duration of post-ACLR physiotherapy treatment was associated with better patient

outcomes. Overall, the level of evidence for the *Duration* studies is best described as 'Conflicting' (Van Tulder et al., 2003).

3.6 Discussion

3.6.1 Summary of Main Findings

The literature search identified 15 articles where post-ACLR physiotherapy treatment data could be extracted from and used to determine the relationship between the quantity and duration of physiotherapy treatment and patient outcomes following ACLR. Based on the findings of the selected studies, it is not clear if the quantity and duration of physiotherapy treatment significantly influences patient outcomes following ACLR. Considerable heterogeneity in the methodologies of the selected studies regarding sample size, time from ACL injury to ACLR, the dosage of post-ACLR physiotherapy treatment, outcome measures used, and final evaluation timeframes likely contributed to the inconclusive findings.

3.6.2 Comparison to Existing Literature

Previous systematic reviews have reported the quantity of physiotherapy supervision during post-operative rehabilitation following ACLR does not significantly influence patient outcomes (Andersson et al., 2009; Gamble et al., 2021; Kruse et al., 2012; Lobb et al., 2012; Risberg et al., 2004; van Melick et al., 2016; Wright et al., 2008). All seven reviews included at least three studies from the current review, and all highlighted significant methodological inadequacies in the selected studies, including small sample sizes, absence of sample size calculation, inadequate randomisation, non-blinding of assessors, gender bias, and no reporting of compliance.

As part of wider systematic reviews on post-operative rehabilitation following various knee surgeries, a clear benefit of supervised rehabilitation over unsupervised/home-based rehabilitation following ACLR could not be established (Coppola & Collins, 2008; Papalia et al., 2013). A recent scoping review on the frequency and duration of supervised rehabilitation following ACLR, which included 11 of the 15 studies from the current review, concluded moderately or minimally supervised rehabilitation is at least as effective as fully supervised high-frequency rehabilitation, and at least 6 months of

supervised rehabilitation is associated with more favourable outcomes after ACLR (Walker et al., 2020).

Several inconsistencies were noted between previous reviews and the current review regarding assessment of methodological quality for selected studies. For example, the study by Grant et al (2010) was scored 4/10 by Gamble et al (2021), indicating a lower quality study, but the current review scored Grant et al (2010) at 93%, indicating a high-quality study. The study by Ugutmen et al (2008) scored 90/100 by Papalia et al (2013), which suggests a low risk of bias, whereas the Quality Index of Ugutmen et al (2008) in the current review was scored as 36%, which suggests a high risk of bias. As different quality assessment tools assess different biases (Page et al., 2018), whichever tool is chosen to assess the methodological quality of selected studies has the potential to significantly influence the overall findings of the review.

Nine of the 11 *Quantity* studies compared clinic-based, physiotherapy-led rehabilitation with home-based rehabilitation. The average quantity and duration of physiotherapy for clinic-based rehabilitation and home-based rehabilitation was 21 treatments over 26 weeks and 4 treatments over 25 weeks respectively. In the 12 months following ACLR in New Zealand, patients receive an average of 10-12 physiotherapy treatments, over an average duration of 143-161 days (See sections 2.6.1 and 2.6.2). The majority of Flemish physical therapists use 41-60 treatments over 6-7 months following ACLR (Dingenen et al., 2021). Therefore, the quantity and duration of physiotherapy treatment in the selected studies may not be an accurate reflection of everyday physiotherapy practice. To increase external validity, future research on ACLR rehabilitation should include interventions that replicate usual physiotherapy practice.

In the first 12 weeks following ACLR, 25-38 rehabilitation sessions have been recommended (Adams et al., 2012), with a physiotherapist review at least every two weeks to ensure adequate progress is maintained (Filbay & Grindem, 2019). Up to 35 physiotherapy treatments may be required in the 12 months following ACLR (See section 2.6.2). The optimal frequency of rehabilitation supervision has yet to be determined (Walker et al., 2020), and the number of physiotherapy treatments

required is likely dependent on the progress of the individual patient (Filbay & Grindem, 2019).

Results from this review, and previous reviews, suggest there is no singular optimal dosage of physiotherapy treatment following ACLR that can be applied to all patients. Contemporary ACLR rehabilitation is now less prescriptive, with progress through rehabilitation determined by the patient's achievement of functional milestones, not time from surgery (Meredith et al., 2020; van Melick et al., 2016). Similarly, the dosage of post-ACLR physiotherapy treatment should also not be pre-determined, but instead be the end-product of the quantity and duration of treatment required for the patient to achieve their post-operative goals (Filbay & Grindem, 2019).

Other person-related factors, such as age, gender, activity levels, and concomitant injury at ACLR potentially have a greater effect on post-operative outcomes than the dosage of physiotherapy treatment. The average age of participants across all 15 studies in the current review was 28 years, with 27% of participants female. Outcomes for patients over 30 years of age, and for female patients, are typically worse following ACLR (Senorski, Svantesson, Baldari, et al., 2019; Tan et al., 2016). Therefore, a high percentage of male participants, and participants under 30 years of age, in a sample could result in an artificially high number of participants achieving better outcomes. However, a significant percentage of ACL injuries occur in females and in people over 30 years of age (Sanders, Maradit, Bryan, Larson, et al., 2016). Therefore, future ACL research should ensure a distribution of participants related to age and gender that represents of the current demographic of ACL injury.

A higher activity level prior to ACL injury is associated with a higher activity level following ACLR (Dunn et al., 2010); however, it is not clear if patient activity level influences the dosage of physiotherapy treatment required following ACLR. Elite athletes may require more advanced rehabilitation and a greater level of supervision than recreational athletes, or conversely, elite athletes may possess a higher level of motivation to complete rehabilitation, leading to a lesser need for supervision (Gamble et al., 2021). For multiple reasons, including the dosage of post-ACLR physiotherapy, a greater percentage of elite athletes return to pre-injury activity levels compared to non-elite athletes (Lai et al., 2018). Future research should investigate the dosage of

physiotherapy required to achieve acceptable outcomes in ACLR patients who encompass the spectrum of activity levels.

Across 13 of the 15 studies in the current review, the time between ACL injury and ACLR ranged from 56 days to 18 years, with two studies not reporting a time (Rhim et al., 2021; Schenck et al., 1997). A longer time to ACLR is associated with an increased risk of secondary meniscal and chondral injury due to recurrent instability episodes (Granan, Bahr, et al., 2009; Sommerfeldt et al., 2018), and the presence of meniscal or chondral injury at the time of ACLR is associated with worse patient outcomes (Cinque et al., 2018; Cox et al., 2014). Therefore, a longer time between injury and ACLR could negatively influence patient outcomes. Only seven of 15 studies in the current review reported excluding participants with concomitant meniscal or chondral injuries at the time of ACLR, which, when combined with the wide range of times between injury and surgery, could have influenced the results of the studies in this review.

Overall, findings from the current review add to the previous literature that indicates the quantity and duration of physiotherapy treatment following ACLR does not appear to significantly influence post-operative outcomes. Previous reviews have focused on the level of supervision during post-ACLR rehabilitation, or home-based verses clinic-based rehabilitation, rather than the actual quantity and duration of physiotherapy treatment. The current review is therefore unique, as it is the first review to specifically address the quantity and duration of physiotherapy treatment following ACLR.

3.6.3 Quality of Selected Studies

The average Downs and Black score for all studies in the current review was 16.9/28 (range 8-26), which equates to an average Quality Index of 60%. Overall, the level of evidence is best summarised as 'Conflicting' (Van Tulder et al., 2003). Several methodological issues can be identified within the selected studies. Regarding the *Quantity* studies, only one – Hohmann et al. (2011) – evaluated the effect of a physiotherapist-led rehabilitation program versus a fully unsupervised rehabilitation program. Across all other *Quantity* studies, both study groups received a degree of physiotherapist input during rehabilitation, with the quantity of that input differing between groups. It is possible the difference in the number of physiotherapy

treatments between study groups was not sufficient to show any significant between-group differences (Gamble et al., 2021). The lack of outcome data for completely unsupervised subjects needs to be considered when evaluating the evidence that a home-based exercise program is equally effective as a clinic-based program (Lobb et al., 2012).

Only 25% of studies in the current review reported, or attempted to measure, participant compliance with rehabilitation protocols. Increased compliance with rehabilitation following ACLR is associated with better patient outcomes (Han et al., 2015; Pizzari et al., 2005). Compliance data is an important variable due to the dose-response relationship for effectiveness (Risberg et al., 2004). Measuring participant compliance with unsupervised rehabilitation may enable a more accurate comparison with patient outcomes following supervised rehabilitation.

Studies published more recently have shown a positive association between the quantity of post-ACLR rehabilitation and patient outcomes (Walker et al., 2020), and results of the current review support that finding. Three *Quantity* studies in the current review were published from 2019 onwards (Lim et al., 2019; Przybylak et al., 2019; Rhim et al., 2021) – all reported a greater quantity of post-ACLR physiotherapy treatment was associated with improved patient outcomes. Six *Quantity* studies in the current review were published prior to 2010 (Beard & Dodd, 1998; Fischer et al., 1998; Grant et al., 2005; Revenäs et al., 2009; Schenck et al., 1997; Ugutmen et al., 2008) – none reported an association between a greater amount of post-ACLR physiotherapy treatment and improved patient outcomes. There is little difference between the methodological quality of the newer verses the older studies, with the average Quality Index of the post-2019 studies being 57% (range 46-64%), and the average Quality Index of the pre-2010 studies being 59.5% (range 29-89%).

There was no clear relationship between methodological quality and the overall findings of the *Quantity* studies. Four *Quantity* studies scored greater than 70% on the Quality Index. One study reported the quantity of post-ACLR physiotherapy treatment had no effect on patient outcomes (Beard & Dodd, 1998), with three reporting equivocal findings regarding the quantity of post-ACLR physiotherapy treatment and patient outcomes (Grant & Mohtadi, 2010; Grant et al., 2005; Revenäs et al., 2009).

Three studies scored less than 50% on the Quality Index – two reported the quantity of post-ACLR physiotherapy treatment had no effect on patient outcomes (Schenck et al., 1997; Ugutmen et al., 2008) and one reported a greater amount of post-ACLR physiotherapy treatment was associated with improved patient outcomes (Przybylak et al., 2019).

The timing of the final evaluation following a post-ACLR intervention could influence the overall findings of a study. If the final evaluation was performed when subjects are unlikely to have achieved optimum function, then the final evaluation may not fully capture the total effects of any intervention. Functional measures can improve for up to two years after ACLR (Roewer et al., 2011). Four *Quantity* studies reported results with a follow-up period of six months or less after ACLR – two reported the quantity of post-ACLR physiotherapy treatment had no effect on outcomes (Beard & Dodd, 1998; Fischer et al., 1998), one reported less physiotherapy treatment resulted in better outcomes (Grant et al., 2005), and one reported more physiotherapy treatment resulted in better outcomes (Lim et al., 2019). The remaining seven *Quantity* studies used follow-up periods of 12 months or greater (range 12-38 months) – two studies reported the quantity of post-ACLR physiotherapy treatment had no effect on outcomes (Schenck et al., 1997; Ugutmen et al., 2008), two reported more physiotherapy treatment is associated with improved patient outcomes (Przybylak et al., 2019; Rhim et al., 2021), one reported less physiotherapy treatment is associated with improved outcomes (Grant & Mohtadi, 2010), and two reported improved outcomes with more and less physiotherapy treatment (Hohmann et al., 2011; Revenäs et al., 2009). Overall, our results indicate the timing of the final subject evaluation following post-ACLR rehabilitation has little influence on the results of the *Quantity* studies.

With regards to *Duration* studies, two reported the duration of post-ACLR physiotherapy treatment had no effect on patient outcomes – both were rated as 'Moderate' quality, were published earlier, and had longer follow-up periods (24 months) (Beynnon et al., 2011; Beynnon, Uh, et al., 2005). Two studies reported a longer duration of post-ACLR physiotherapy treatment resulted in better outcomes – both were rated 'Limited' quality, were published later, and had shorter follow-up periods (27-33 weeks) (Królikowska, Czamara, Szuba, et al., 2018; Królikowska,

Sikorski, et al., 2018b). Due to lack of published studies, it is not possible to conclude if study quality, date of publication, and the timing of the final subject evaluation influenced the findings of the *Duration* studies.

3.6.4 Limitations

This review is not without limitations. Of the 15 included studies, only two *Duration* studies were conducted with the expressed aim of prospectively examining the effects of the quantity or duration of post-ACLR physiotherapy treatments on patient outcomes. None of the 11 *Quantity* studies specifically investigated the effects of the quantity of post-ACLR physiotherapy treatment on patient outcomes. Although the intended purpose of the majority of included studies did not completely align with the intended purpose of the review, it was considered appropriate to include them, as the dosage of post-ACLR physiotherapy treatment could be extracted from the articles. As such, the conclusions of this review regarding the effects of the quantity and duration of post-ACLR physiotherapy treatment are based on data that was not collected for the purpose for which it has been used. As we excluded articles not published in English and did not search for unpublished studies, we may not have captured all the relevant literature. Considerable heterogeneity between the included studies precluded quantitative meta-analysis, while preventing any between-study comparison of interventions and outcomes.

3.7 Conclusions

The current review has not clearly established the quantity and duration of physiotherapy treatment following ACLR has a significant effect on patient outcomes. Similar outcomes are achieved irrespective of the dosage of physiotherapy treatment. This review adds to the findings of previous reviews that have shown no clear benefit of supervised rehabilitation over home-based or unsupervised rehabilitation following ACLR. Constant monitoring of post-ACLR rehabilitation by a physiotherapist does not appear necessary, although regular therapist review allows for ongoing patient assessment, education, and progression. High-quality RCTs investigating the optimal dosage of physiotherapy treatment following ACLR, or the level of supervision required during post-ACLR rehabilitation, to achieve acceptable patient outcomes are lacking.

Chapter 4

The Relationship Between Physiotherapy Treatment and Patient-Reported Outcomes Following Anterior Cruciate Ligament Reconstruction in New Zealand

This chapter is comprised of the following manuscript:

Fausett, W., Reid, D., & Larmer, P., & Garrett, N. (2023). Patient acceptance of knee symptoms and function after anterior cruciate ligament reconstruction is improved by physiotherapy treatment. *New Zealand Journal of Physiotherapy, 51*(1), 53–69. doi:10.15619/NZJP/51.1.07

To maintain consistency of style throughout the thesis, the manuscript is presented here in a format that differs slightly to the published article (Appendix C).

4.1 Preface

In NZ, ACLR rehabilitation typically equals physiotherapy treatment. Results from chapter two show NZ ACLR patients receive a low dosage of physiotherapy treatment following surgery. As objective patient outcome data was not regularly collected by the provider during the course of treatment, it is not possible to determine the effectiveness of that physiotherapy treatment. Furthermore, results from chapter three revealed previous research has not established a clear relationship between the dosage of post-ACLR physiotherapy treatment and patient outcomes. Therefore, this study will match physiotherapy treatment data and patient-reported outcome data, using a large cohort of NZ ACLR patients, to determine the nature of the relationship between post-ACLR physiotherapy treatment and patient outcomes.

4.2 Abstract

Physiotherapy is considered an important component of rehabilitation following anterior cruciate ligament reconstruction (ACLR). The relationship between physiotherapy treatment and patient-reported outcomes following ACLR in New Zealand (NZ) is not clear. We used repeated measures logistic regression to examine the relationship between patient-reported outcome data from the NZ ACL Registry and physiotherapy treatment data from the Accident Compensation Corporation (ACC). Outcome measures utilised were the patient acceptable symptom state (PASS) on the Knee Injury Osteoarthritis and Outcome Score (KOOS^4) and a normative score on the Marx Activity Rating Scale (MARS) within 24 months of ACLR. Data from 5,345 individuals were included in the final analysis, with a mean (SD) of 11.7 (10.5) (range 0–91) physiotherapy treatments received, over an average (SD) of 185 (153) (range 0–725) days, in the two years following ACLR. Physiotherapy treatment post-ACLR increased the likelihood of achieving a KOOS^4 PASS score at 6 and 12 months, but not at 24 months, following surgery. Physiotherapy did not increase the likelihood of achieving a normative MARS score in the 24 months after ACLR. Multiple factors likely contribute to people who have had an ACLR in NZ receiving a low dosage of physiotherapy treatment following surgery. Physiotherapy treatment after ACLR may increase patient acceptance of any post-surgical symptoms and functional limitations, but the effect on post-operative activity levels is less clear.

4.3 Introduction

Functional rehabilitation, including lower limb strength and neuromuscular training, is generally recommended following anterior cruciate ligament reconstruction (ACLR) to increase the likelihood of a patient achieving their post-surgical goals (Andrade et al., 2019). In NZ, physiotherapists typically oversee rehabilitation following ACLR (See section 2.3). Therefore, the quantity and duration of post-operative physiotherapy treatment likely provides an accurate estimation of the dosage of rehabilitation received following ACLR in NZ. There remains no consensus on the optimal quantity and duration of post-ACLR physiotherapy treatment (Walker et al., 2020), with equivocal evidence as to whether the dosage of physiotherapy treatment following ACLR significantly influences patient-reported outcome scores, knee strength,

functional ability, and graft re-rupture rates (Beynnon et al., 2011; Grant et al., 2005; Hohmann et al., 2011; Przybylak et al., 2019; Rhim et al., 2021; Vincent et al., 2017).

The dosage of physiotherapy treatment received by community-based ACLR patients following surgery can vary widely. Retrospective studies show ACLR patients receive between 15-50+ physiotherapy treatments following surgery (Burroughs et al., 2021; Christensen et al., 2017; Dempsey et al., 2019; Miller et al., 2017). The number of treatments physiotherapists report using following ACLR ranges from 20 to 60 but can exceed 100 (Dingenen et al., 2021; Ebert et al., 2019; Korakakis et al., 2021). The reported duration of post-ACLR rehabilitation for community-based ACLR patients ranges from 127-175 days (Christensen et al., 2017; Dempsey et al., 2019; Miller et al., 2017), with the duration rarely exceeding six months (Dunphy & Gardner, 2020; Ebert et al., 2018; Edwards et al., 2018).

Outcomes following ACLR are typically evaluated with a combination of functional measures and patient-reported outcomes measures (PROMs) (Filbay & Grindem, 2019). There are over 50 PROMs related to the anterior cruciate ligament (ACL) deficient knee (Johnson & Smith, 2001); however, the Knee Injury Osteoarthritis and Outcome Score (KOOS) and the Marx Activity Rating Scale (MARS) are two PROMs consistently utilised in ACL research and by ACL registries (Kanakamedala et al., 2016; Senorski, Svantesson, Engebretsen, et al., 2019). As discrepancies can exist between post-operative PROM scores and patient satisfaction levels, the concept of a patient acceptable symptom state (PASS) may better facilitate interpretation of a PROM (Cristiani, Mikkelsen, et al., 2020; Wright et al., 2015). The PASS is defined as the PROM score beyond which patients consider themselves well (Tubach, Wells, et al., 2005). PASS thresholds have been developed for each subscale of the KOOS (Muller et al., 2016), and measurement of the PASS is a valuable complement to the KOOS in ACL injury (Svantesson et al., 2020). PASS thresholds, which are derived from a population with the condition of interest, differ from normative scores, which are derived from people who have never had the condition.

The Accident Compensation Corporation (ACC) of New Zealand (NZ) is a government-funded no-fault insurance scheme, which funds treatment and rehabilitation costs for personal injuries caused by an accident, as defined by the ACC Act of 2001 (Todd,

2011). An injury claim is lodged on behalf of the patient by their treatment provider, and if accepted, treatment costs are funded under that specific claim (Bismark & Paterson, 2006). As ACL injuries in NZ are typically the result of an accident (Gianotti et al., 2009), treatment and rehabilitation costs for ACL injuries in NZ are usually met by ACC. ACC is the primary funder of private physiotherapy services in NZ (Reid & Larmer, 2007); however, patients receiving treatment from private physiotherapists are typically charged a co-payment, as ACC funding does not usually cover the full cost of the treatment (Fitzjohn, 2007). ACC requires physiotherapy providers to collect visual analogue scale (VAS) pain scores and patient specific functional scale (PSFS) scores from patients; however, ACC does not collect this data from providers. Therefore, although ACC has visibility regarding the dosage of rehabilitation provided following ACLR, it has no knowledge of the specific outcome, or effectiveness, of that rehabilitation. ACC has also historically placed limits on the number of physiotherapy treatments it would fund following a musculoskeletal injury, with the maximum number of treatments following ACL injury being 16. Once the treatment number limit has been reached, the physiotherapist must apply to ACC for funding of additional treatments.

ACL registries provide a unique opportunity to understand and interpret factors affecting patient-reported outcomes after ACLR (Prentice et al., 2018). The NZ ACL Registry has been collecting PROM data for NZ ACLR patients since 2014, with almost 90% of ACLRs performed in 2020 enrolled by the registry (New Zealand ACL Registry, 2021). To date, it has not been possible to correlate these patient outcomes with the rehabilitation received, as the NZ ACL Registry does not collect data related to post-surgical physiotherapy treatment. Therefore, the purpose of this study is to explore the quantity and duration of physiotherapy treatment following primary, unilateral ACLR in NZ, and to determine the relationship between that dosage of physiotherapy treatment and patient-reported outcomes in the two years following surgery.

4.4 Materials and Methods

4.4.1 Data Sources

The NZ ACL Registry forwarded the following outcome data to ACC's Analytics and Research unit in a password-protected Microsoft Excel spreadsheet: pre-ACL injury

MARS score, pre-ACLR KOOS/MARS scores, and post-ACLR KOOS/MARS scores at 6-, 12-, and 24-months. As outcome data was collected independent of the physiotherapy provider, all subjects had the opportunity to complete PROMs at all data collection points, even if the subject was not engaged in physiotherapy treatment at the time of PROM data collection.

Using subject identifiers – National Health Index (NHI) number, and/or date of birth, and/or date of ACL injury – outcome data was matched to the ACC claim the ACLR was funded under. Once subject outcome data and the ACC claim were matched, the following variables were extracted from the ACC claims management software system (FinEos) into a password-protected Microsoft Excel spreadsheet:

- Age at date of ACLR
- Gender
- Date of ACLR.
- Number of days between ACL injury and ACLR.
- Number of physiotherapy treatments in the 12 months prior to ACLR.
- Number of physiotherapy treatments between 0-6, 7-12, and 13-24 months post-ACLR.
- Date of first and last physiotherapy treatment after ACLR.
- Whether the subject had received vocational rehabilitation following ACLR.

Once extracted, patient data was de-identified and forwarded to the primary investigator for analysis. Due to the large number of subjects available, subjects were excluded if patient-reported outcome data was either missing or unavailable from more than one post-ACLR time point. Unavailable data was defined as data yet to be collected as that time point after ACLR had not yet been reached. Other exclusion criteria included revision ACLR, as subjective outcomes for this population are typically worse than for primary surgery (Lind et al., 2012; Wright et al., 2012), or non-ACC funded ACLR, as no physiotherapy treatment data would be available from ACC for these subjects.

4.4.2 Outcome Measures

The primary outcomes were the achievement of a KOOS^4 PASS score or a normative MARS score. The KOOS is composed of 5 subscales: pain, knee-related symptoms, activities of daily living (ADL), function in sport and recreation, and knee-related quality of life (QoL) (Roos et al., 1998). Items on the KOOS are scored from 0 (no problem) to 4 (extreme problem) on a 5-point Likert scale. Scores from each subscale are transformed to a 0-100 scale, with zero representing "extreme knee problems" and 100 representing "no knee problems". The KOOS^4 is an average score of four subscales, where the ADL subscale is excluded to avoid a ceiling effect, as younger, more active patients rarely have difficulties with activities of daily living (Frobell et al., 2010). Excluding the ADL subscale mitigates the risk of a high score on the ADL subscale artificially inflating the KOOS^4 score.

The achievement of a KOOS^4 PASS score was based on individual KOOS subscale threshold values established by Muller et al. (2016), who asked ACLR patients: "Taking account of all the activity you have during your daily life, your level of pain, and also your activity limitations and participation restrictions, do you consider the current state of your knee satisfactory?" (Muller et al., 2016). Corresponding PASS values for the KOOS subscales were: Pain > 88.9, Symptoms > 57.1, Sport and Recreation > 75.0, QoL > 62.5, which equated to a KOOS^4 PASS score of 70.9. Subjects were not required to achieve a PASS score on each of the four subscales.

The MARS is a knee-specific questionnaire that evaluates activity level in people with various knee disorders (Marx et al., 2001). The MARS assesses the ability to perform four functional activities: running, cutting, decelerating, and pivoting. Participants record how often they perform these activities on a 0-4 scale, with 4 being most active. The maximum possible MARS score is 16. We used a MARS score of 11 for females and 12 for males as normative values (Cameron et al., 2015).

4.4.3 Statistical Analysis

A comparative analysis of descriptors for subjects included and subjects excluded was performed. Initial descriptive analysis examined the distributions of the outcome and explanatory measures. The available confounding factors were identified as gender, age group, received vocational rehabilitation post-ACLR, number of days between ACL

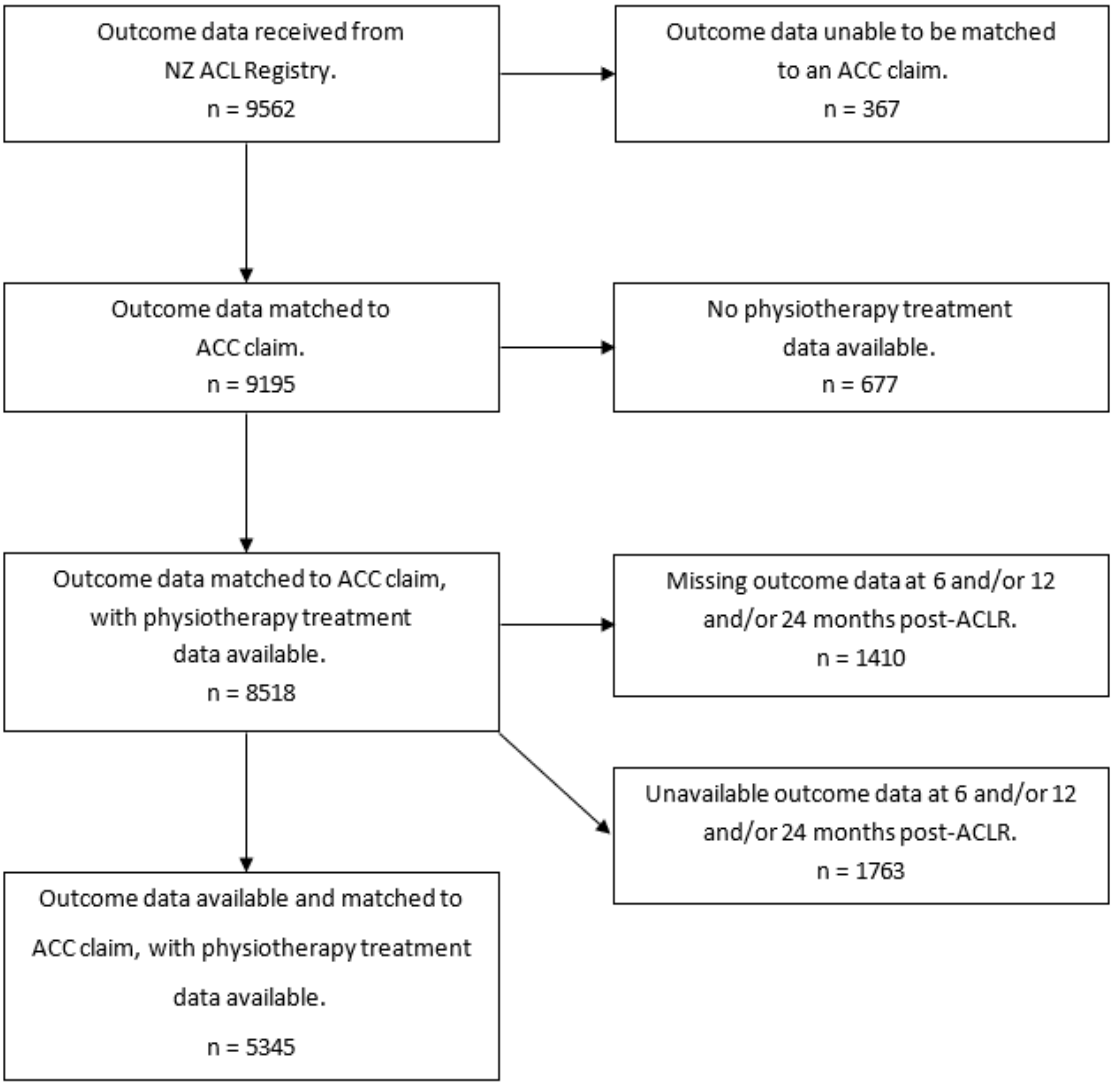
injury and ACLR, and for MARS scores, a pre-injury MARS score. A repeated measures logistic regression with unstructured correlation was used to examine the association between dichotomous outcome measures and physiotherapy treatment, adjusting for the confounders and time varying effects.

4.5 Results

Outcome data for 9562 subjects was received from the NZ ACL registry (Figure 4.1). Outcome data was unable to matched to an ACC claim for 4% of subjects due to a missing NHI number, date of birth, or date of ACL injury. Physiotherapy treatment data was not recorded for 7% of subjects. Two out of three post-ACLR outcome data points were either missing or unavailable for 33% of subjects. Sufficient outcome data was available and able to be matched to the corresponding ACC claim, from which physiotherapy treatment data was able to be extracted, for 56% of subjects.

Figure 4.1

Flow chart showing derivation of final data set.



Descriptive analysis of the subject groups included and excluded from the final set revealed the percentage of males differed across all groups, with males more likely to have missing physiotherapy treatment data and missing outcome data (Table 4.1). Subjects with missing outcome data were more likely to be younger at the time of ACLR but less likely to have received vocational rehabilitation (VR). Subjects with missing physiotherapy treatment data had a longer delay to ACLR but were less likely to have received VR.

Table 4.1

Descriptive covariate values for subjects included verses subjects excluded from the final data set.

		Outcome data received from NZ ACL Registry (n = 9562)	Outcome data unmatched to ACC claim (n = 367)	Physiotherapy treatment data missing (n = 677)	Outcome data missing (n = 1410)	Outcome data unavailable (n = 1763)	Physiotherapy treatment data and outcome data available and matched (n = 5345)	p-value*
Gender	Male (%)	57.6	63.2	69.4	70.7	54.3	53.3	<0.0001
Age at ACLR (years; mean ± SD; range)		27.8 ± 11.1 (8-70)	28.8 ± 10.5 (11-64)	29.4 ± 10.9 (9-70)	25.6 ± 9.3 (10-63)	28.7 ± 10.8 (10-69)	29.4 ± 11.2 (8-69)	
Age at ACLR	8-20 yrs (%)	29	20	23	36	26	24	
	21-30 yrs (%)	38	47	38	40	38	37	
	31-40 yrs (%)	18	18	22	15	20	20	
	41-69 yrs (%)	15	15	17	9	16	19	<0.0001
Days from ACL injury to ACLR (mean ± SD; range)		289 ± 723 (12-16025)	290 ± 928 (14-15418)	422 ± 975 (17-8801)	252 ± 637 (16-14406)	234 ± 605 (12-16025)	287 ± 708 (14-12163)	
Days from ACL injury to ACLR	14-79 (%)	26	29	22	27	26	25	
	80-126 (%)	24	20	24	23	24	25	
	127-230 (%)	25	23	23	25	29	25	
	231+ (%)	25	23	31	25	21	25	<0.0001
	Missing (%)	-	5	-	-	-	-	
Had vocational rehabilitation	Yes (%)	33.4	-	22.2	40.1	32.3	35.6	
	No (%)	66.6	-	77.8	59.9	67.7	64.4	<0.0001
Pre-injury MARS score (mean ± SD)		11.4 ± 4.9	11.4 ± 5.0	10.4 ± 5.3	11.2 ± 5.2	11.6 ± 4.8	11.7 ± 4.8	

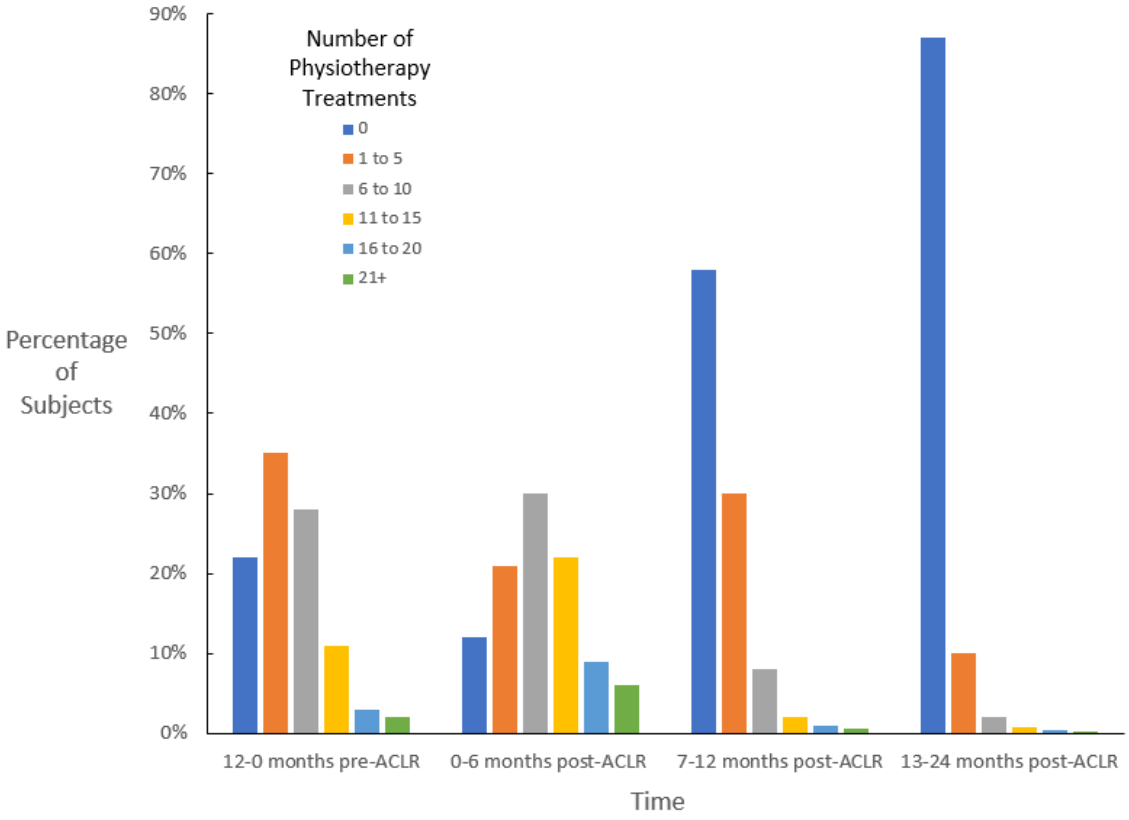
NZ = New Zealand; ACL = anterior cruciate ligament; ACLR = anterior cruciate ligament reconstruction; ACC = Accident Compensation Corporation; SD = standard deviation; yrs = years. *chi-square test.

4.5.1 Physiotherapy Treatment Following ACLR

The average number of physiotherapy treatments in the 12 months prior to ACLR was 5.5 ± 5.2 (range 0-39) (Figure 4.2). The average number of physiotherapy treatments from 0-6 months post-ACLR was 9.2 ± 7.2 (range 0-67), from 7-12 months post-ACLR was 1.9 ± 3.7 (range 0-54), and from 13-24 months post-ACLR was 0.6 ± 2.4 (range 0-35). Average total physiotherapy treatments in the 24 months post-ACLR was 11.7 ± 10.5 (range 0-91). The percentage of subjects who did not receive physiotherapy treatment pre-ACLR and from 0-6-, 7-12-, and 13-24-months post-ACLR was 22%, 12%, 57%, and 88% respectively (Figure 4.2).

Figure 4.2

Average number of physiotherapy treatments in the 12 months prior to, and 24 months following, ACLR.

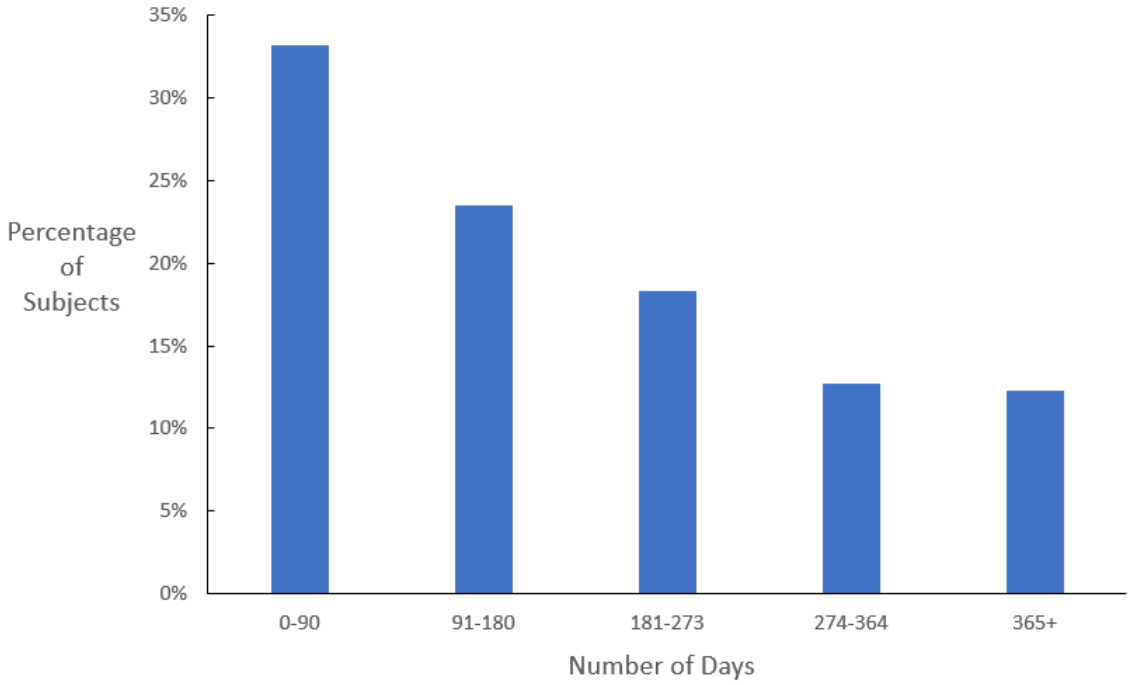


The duration of post-ACLR physiotherapy treatment was less than six months for 57% of subjects, while post-ACLR physiotherapy treatment lasted longer than nine months

for 25% of subjects (Figure 4.3). The average number of days from the first post-ACLR physiotherapy treatment to the last treatment was 185 ± 153 days (range 0-725).

Figure 4.3

Number of days between first and last physiotherapy treatment following ACLR.



4.5.2 Patient Reported Outcomes Following ACLR

KOOS[4]

The likelihood of a subject achieving a KOOS[4] PASS score following ACLR increased significantly over time (p = <0.0001) (Table 4.2). The percentage of subjects achieving a KOOS[4] PASS score pre-ACLR, and at 6-, 12-, and 24-months post-ACLR was 17%, 53%, 70%, and 75% respectively (Figure 4.4).

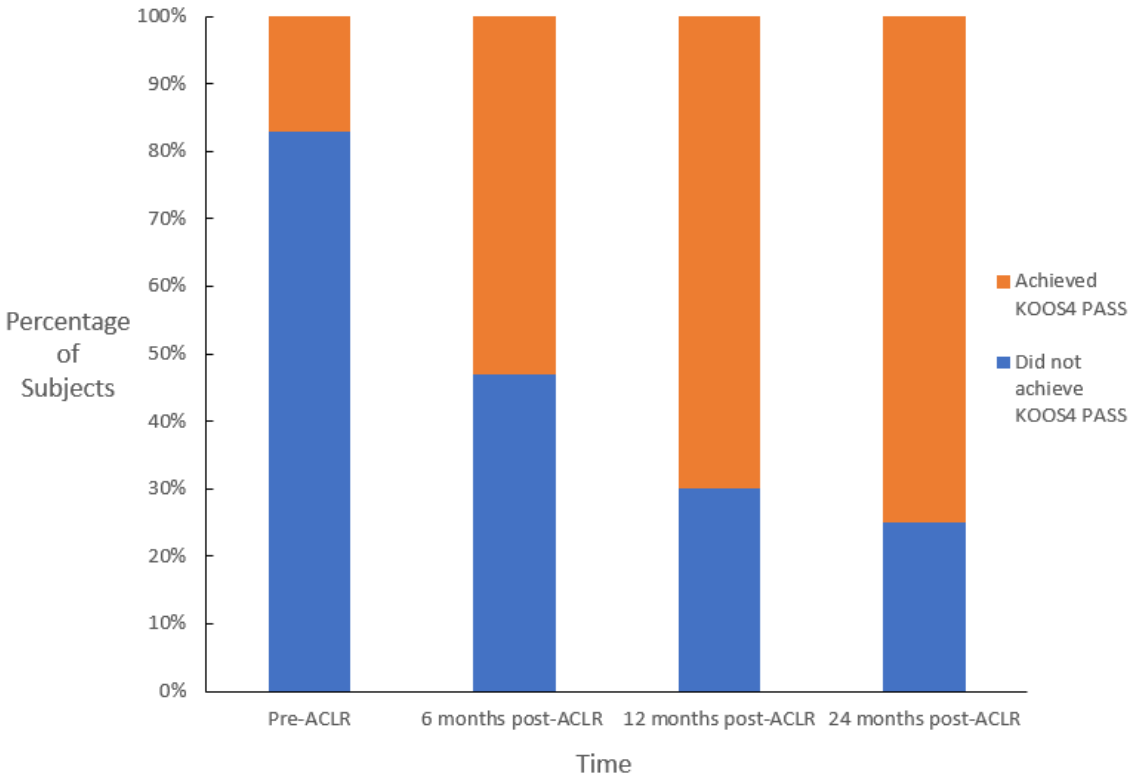
Table 4.2

Unadjusted odds rations for the likelihood of achieving a KOOS[4] PASS score following ACLR.

Time since ACLR	Odds Ratio	95% Confidence Interval	p-value
Pre-ACLR	1.00	-	
6 months	5.34	(4.92,5.79)	
12 months	10.87	(9.96,11.86)	
24 months	13.99	(12.64,15.49)	<0.0001

Figure 4.4

Subjects achieving a KOOS[4] PASS score over time.



MARS

The likelihood of a subject achieving a normative MARS score following ACLR increased significantly over time (p = <0.0001) (Table 4.3). The percentage of subjects achieving a normative MARS score pre-ACLR, and at 6-, 12-, and 24-months post-ACLR was 5%, 11%, 23%, and 28% respectively (Figure 4.5).

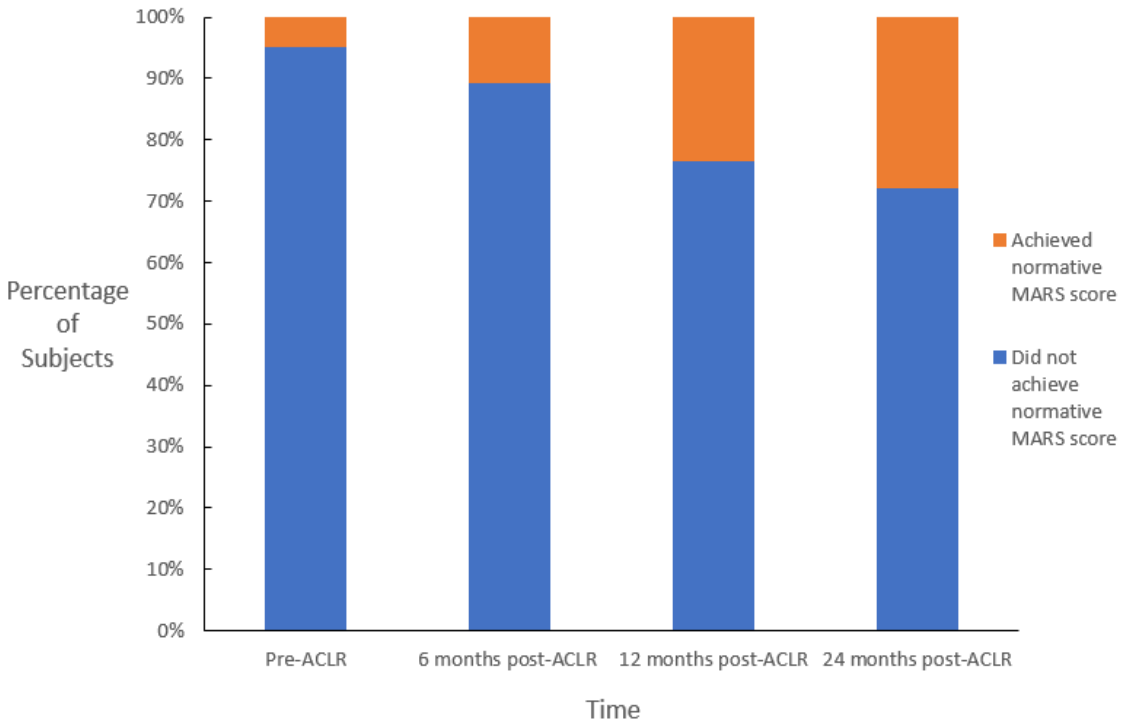
Table 4.3

Unadjusted odds ratios for the likelihood of achieving a normative MARS score following ACLR.

Time since ACLR	Odds Ratio	95% Confidence Interval	p-value
Pre-ACLR	1.00		
6 months	2.20	(1.90,2.55)	
12 months	5.86	(5.10,6.73)	
24 months	7.53	(6.52,8.70)	<0.0001

Figure 4.5

Subjects achieving a normative MARS score over time.



4.5.3 Relationship Between Physiotherapy Treatment and Patient Reported Outcomes – Univariate Analysis

Post-ACLR physiotherapy treatment was grouped into 0, 1, 2-4, and 5+ treatments, as these treatment numbers approximated quartile divisions. Initial analyses showed a statistically significant increase in the likelihood of achieving a KOOS[4] PASS score for one physiotherapy treatment over no physiotherapy treatments from 0-6 and 7-12 months post-ACLR ($p = 0.04$), with lesser non-significant increases for 2-4 and 5+ treatments (Table 4.4). There was no effect of different quantities of post-ACLR physiotherapy treatment on the likelihood of achieving a normative MARS score. Therefore, the physiotherapy treatment groups were collapsed into whether physiotherapy treatment was present or not.

Table 4.4

Unadjusted odds ratios for different quantities of physiotherapy treatment and the likelihood of achieving a KOOS[4] PASS score following ACLR.

Time since ACLR	Number of Physiotherapy Treatments	Odds Ratio	95% Confidence Interval
0-6 months	0	1.00	-
	1	1.45	(1.01,2.09)
	2-4	1.20	(0.96,1.49)
	5+	1.18	(0.99,1.39)
7-12 months	0	1.00	-
	1	1.31	(1.08,1.59)
	2-4	1.12	(0.96,1.31)
	5+	1.17	(0.99,1.39)
13-24 months	0	1.00	-
	1	0.90	(0.62,1.33)
	2-4	0.88	(0.60,1.27)
	5+	0.77	(0.50,1.17)

KOOS^4

The percentage of subjects who achieved a KOOS^4 PASS score at each time point, based on whether they received physiotherapy treatment, is shown in Figure 4.6. Overall, there was a significant association between receiving physiotherapy treatment and the likelihood of achieving a KOOS^4 PASS score following ACLR ($p = 0.0024$), with physiotherapy treatment between 7-12 months associated with an increased likelihood of achieving a KOOS^4 PASS score at 12 months post-ACLR (Table 4.5). Physiotherapy treatment between 13-24 months was associated with a non-significant decreased likelihood of achieving a KOOS^4 PASS score at 24 months post-ACLR.

Figure 4.6

Subjects achieving a KOOS^4 PASS score and if they received physiotherapy treatment.

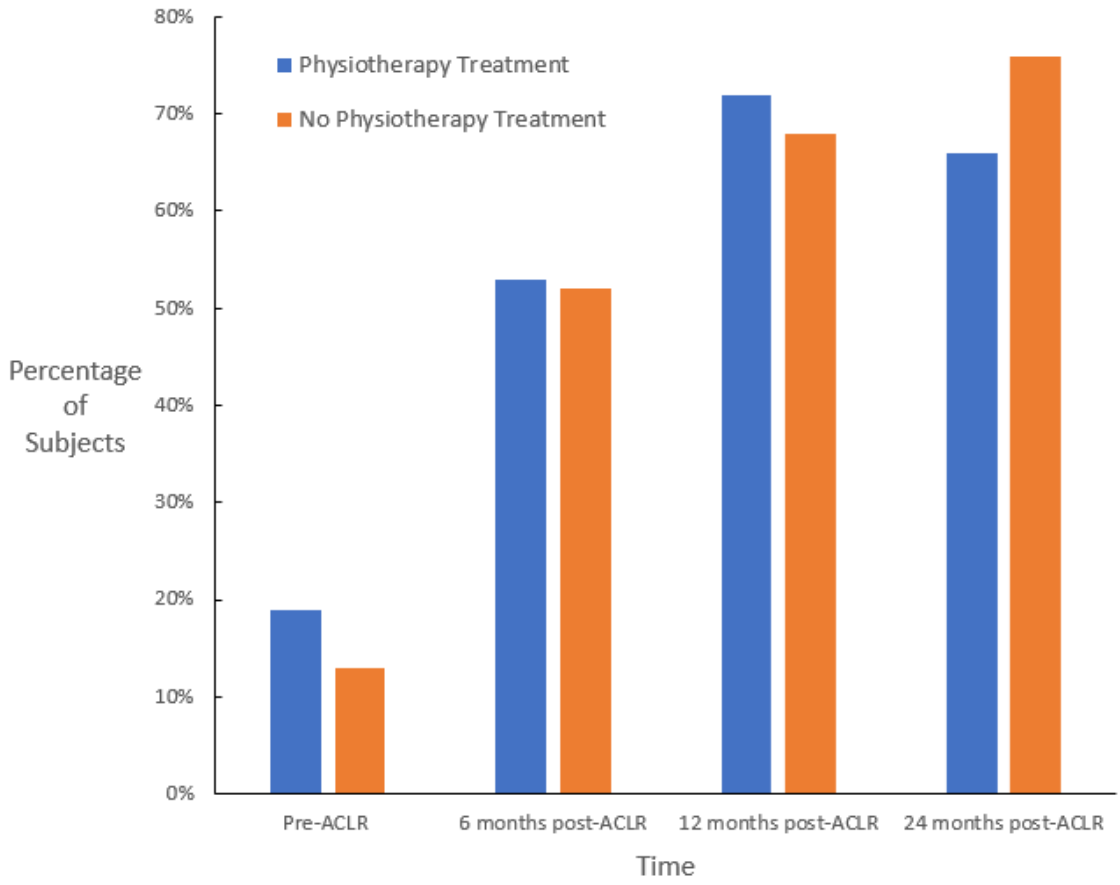


Table 4.5

Unadjusted odds ratios for subjects receiving physiotherapy treatment and the likelihood of achieving a KOOS[4] PASS score following ACLR.

Time since ACLR	Physiotherapy Treatment	Odds Ratio	95% Confidence Interval
0-6 months	No	1.00	
	Yes	1.12	(0.95,1.31)
7-12 months	No	1.00	
	Yes	1.21	(1.08,1.36)
13-24 months	No	1.00	
	Yes	0.86	(0.68,1.09)

MARS

The percentage of subjects who achieved a normative MARS score at each time point, based on whether they received physiotherapy treatment, is shown in Figure 4.7. Overall, there was a significant association between receiving physiotherapy treatment and the likelihood of achieving a normative MARS score following ACLR ($p = 0.0003$), with physiotherapy treatment between 7-12 and 13-24 months associated with an increased likelihood of achieving a normative MARS score at 12- and 24-months after surgery respectively (Table 4.6).

Figure 4.7

Subjects achieving a normative MARS score and if they received physiotherapy treatment.

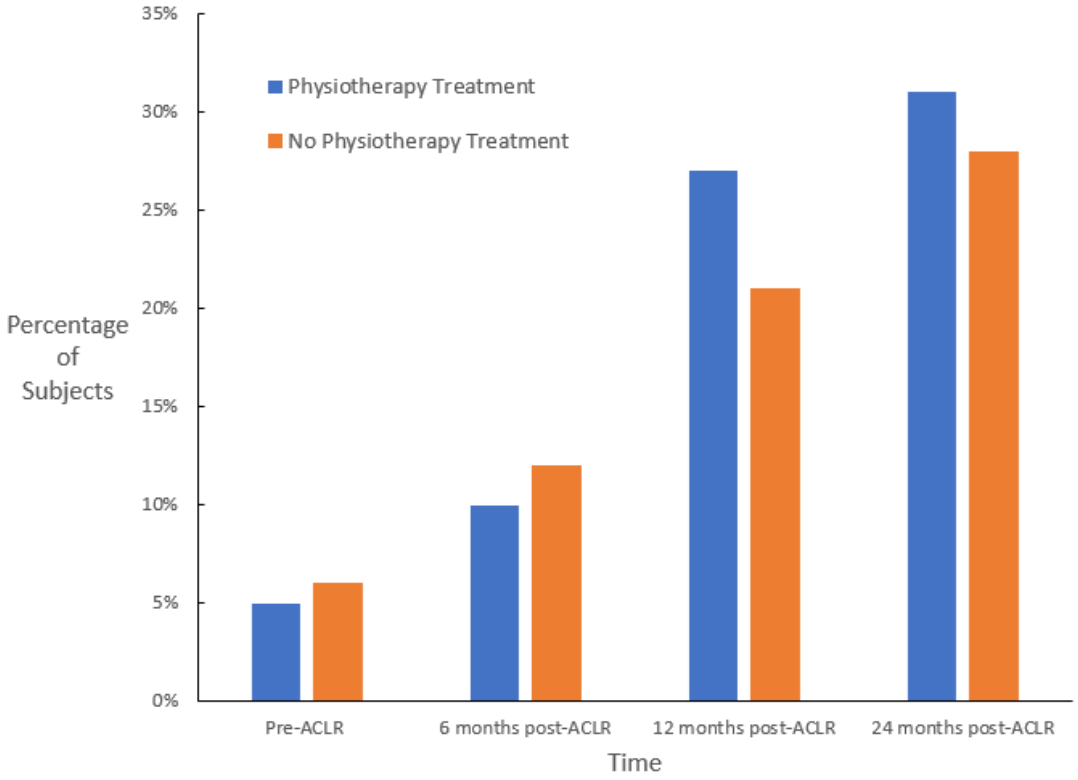


Table 4.6

Unadjusted odds ratios for subjects receiving physiotherapy treatment and the likelihood of achieving a normative MARS score following ACLR.

Time since ACLR	Physiotherapy Treatment	Odds Ratio	95% Confidence Interval
0-6 months	No	1.00	
	Yes	0.95	(0.71,1.27)
7-12 months	No	1.00	
	Yes	1.27	(1.12,1.46)
13-24 months	No	1.00	
	Yes	1.40	(1.12,1.75)

4.5.4 Relationship Between Physiotherapy Treatment and Patient Reported Outcomes – Multivariate Analysis

When adjusted for confounding variables, there was a significant relationship between physiotherapy treatment and likelihood of achieving a KOOS[4] PASS score following ACLR (p = 0.0035) (Table 4.7) (Appendix J). Physiotherapy treatment between 0-6 months and 7-12 months increased the likelihood of achieving a KOOS[4] PASS score at 6- and 12- months respectively. However, when adjusted for confounders, the relationship between physiotherapy treatment and the likelihood of achieving a normative MARS score following ACLR did not reach significance (p = 0.15) (Appendix K). Physiotherapy treatment during all post-operative time periods was not associated with an increased likelihood of achieving a normative MARS score at any post-operative time point.

Table 4.7

Adjusted odds ratios for receiving physiotherapy treatment and the likelihood of achieving a KOOS[4] PASS score and a normative MARS score following ACLR.

	Time since ACLR	Physiotherapy Treatment	Odds Ratio	95% Confidence Interval
KOOS[4]	0-6 months	No	1.00	
		Yes	1.19	(1.01,1.41)
	7-12 months	No	1.00	
		Yes	1.18	(1.05,1.33)
	13-24 months	No	1.00	
		Yes	0.84	(0.67,1.07)
MARS	0-6 months	No	1.00	
		Yes	0.91	(0.68,1.23)
	7-12 months	No	1.00	
		Yes	1.13	(0.97,1.31)
	13-24 months	No	1.00	
		Yes	1.24	(0.97,1.58)

4.6 Discussion

The aim of this study was to explore the dosage of physiotherapy treatment following ACLR in NZ, and to determine the relationship between the quantity of physiotherapy treatment and patient-reported outcomes in the two years following surgery. Our results showed physiotherapy treatment in the first 12 months following ACLR was associated with an increased likelihood of achieving a KOOS[4] PASS score. Physiotherapy treatment in the 24 months following ACLR was not associated with an increased likelihood of achieving a normative MARS score. A greater number of physiotherapy treatments following ACLR was not associated with an increased likelihood of achieving a KOOS[4] PASS score or a normative MARS score in the 24 months following surgery. Overall, subjects received a low dosage of physiotherapy treatment following ACLR in NZ.

This is the first study to show a relationship between physiotherapy treatment and the achievement of a KOOS[4] PASS score following ACLR. Other factors associated with achieving a KOOS[4] PASS score after an ACLR include the absence of a concomitant medial collateral ligament injury and receiving a hamstring tendon graft (Senorski et al., 2018). Age, gender, quadriceps symmetry, absence of concomitant cartilage and meniscal injuries, and hop test performance are also associated with achieving PASS scores on subscales of the KOOS following ACLR (Cristiani, Mikkelsen, et al., 2020; Senorski, Svantesson, Baldari, et al., 2019; Senorski et al., 2018). Of these factors, only quadriceps symmetry and hop test performance can be modified by rehabilitation i.e. physiotherapy treatment. Physiotherapy treatment following ACLR has been shown to improve quadriceps and hamstring strength (Dempsey et al., 2019; Rhim et al., 2021; Walston & Barillas, 2021) and lower limb function (Ebert et al., 2018; Lim et al., 2019). Therefore, physiotherapy treatment potentially contributes to the positive correlation between functional performance and KOOS scores following ACLR (Reinke et al., 2011).

Physiotherapy treatment between 13 and 24 months after ACLR was associated with decreased likelihood of achieving a KOOS[4] PASS score, both in the univariate and multivariate analyses, although results did not reach statistical significance. A lower percentage of patients who received physiotherapy treatment from 13-24 months achieved a KOOS[4] PASS score at 24 months. Physiotherapy treatment after ACLR is

recommended to last up to 12 months (van Melick et al., 2016). Therefore, if physiotherapy treatment is required after 12 months, there have potentially been post-operative complications (Eckenrode et al., 2017; Lord et al., 2020), which necessitated prolonged physiotherapy treatment and contributed to a worse outcome.

In the univariate analysis, physiotherapy treatment between 7-12 and 13-24 months after ACLR was associated with a significantly increased likelihood of achieving a normative MARS score. When considered with other confounding variables, there was a trend for physiotherapy treatment between 7-24 months to be associated with an increased likelihood of achieving a normative MARS score, but significance was not reached. The relationship between physiotherapy treatment and MARS scores following ACLR has not been previously reported. However, physiotherapy treatment following ACLR has been associated with higher scores on the Tegner Activity Scale (Przybylak et al., 2019; Revenäs et al., 2009), which, as with the MARS, quantifies activity level following knee injury (Collins et al., 2011).

Not unexpectedly, the percentage of subjects achieving KOOS^4 PASS scores and normative MARS scores improved over time following ACLR. Our results show 75% of ACLR patients perceive their symptoms as acceptable at two years post-surgery, which is consistent with previous research (Ingelsrud et al., 2015). Only 28% of subjects had achieved a normative MARS score at two years post-ACLR. Although the percentage of subjects achieving a normative MARS score increased over time, the average MARS score at 24 months post-ACLR was only 61% of the average pre-injury score, suggesting a low rate of return to pre-injury activity levels after 24 months. Previous research, using MARS data from the same population, reported only 11.1% and 15.5% of ACLR patients in NZ have returned to pre-injury activity levels at 12- and 24-months respectively (Rahardja et al., 2021). Our study therefore adds to the body of work showing a significant number of people do not achieve pre-injury activity levels two years after ACLR (Antosh et al., 2018; Cox et al., 2014; Dunn et al., 2010).

Preliminary analysis of the KOOS^4 data used a normative score as the dependent variable in the statistical model. However, the number of subjects achieving a normative KOOS^4 score at each time point was so low the statistical model failed. Previous research has shown most people do not achieve normative KOOS scores

within two years of ACLR (Herrington, 2013). As a significant number of ACLR patients achieve a PASS score on four out of five KOOS subscales at 12 months after ACLR (Senorski et al., 2018), a KOOS^4 PASS score was therefore selected as a dependent variable. A normative MARS score was selected as a dependent variable in the current study, as to date, no PASS scores have been published for the MARS.

Normative values need to be considered in the context of the population from which they were derived. The normative MARS values used in the current study were derived from a cohort of United States military academy recruits, with an average age of 18.8 ± 0.9 years for males and 18.7 ± 0.7 years for females (Cameron et al., 2015) – the only published normative MARS scores to date. In the current study, average age of subjects at ACLR was 29.5 years for males and 29.3 years for females, with a range from 8-69 – only 11% of subjects were aged 17-19 years. Younger people have higher participation rates in ACL-dependent activities (Eime et al., 2016), which would be reflected in higher MARS scores. Following ACLR, MARS scores decline with increasing age (Randsborg et al., 2022; Spindler et al., 2018). Therefore, the average age of subjects in the current study likely contributed to the low percentage achieving a normative MARS score following ACLR and the MARS may not be appropriate to assess outcomes following ACLR in a population with a wide range of ages.

Patient-reported outcome measures are not routinely utilised by physiotherapists in clinical practice (Jette et al., 2009). Although there is no data on the general utilisation of PROMs by NZ physiotherapists, only 52% of NZ physiotherapists report using PROMs when considering a return to sport (RTS) after ACLR (See section 5.5). Patient-reported outcome data following ACLR in NZ is collected by an ACL Registry – an ACC-funded organisation set up by the Knee and Sports Society, which is a branch of the NZ Orthopaedic Association (New Zealand ACL Registry, 2021). The NZ ACL Registry has no links to physiotherapy providers in NZ. Therefore, the collection of PROM data following ACLR is independent of the providers delivering the post-surgical rehabilitation – independence that eliminates any bias the physiotherapist may introduce during collection of the PROM data. However, collection of the PROM data by the NZ ACL Registry is not correlated specifically to a particular stage of rehabilitation and the physiotherapist overseeing the rehabilitation has no visibility of the PROM scores. PROM data is collected by the NZ ACL Registry at 6-, 12-, and 24-

month intervals following ACLR. More frequent collection of PROM data by the physiotherapist may offer greater insights into the patients rehabilitation progress, with the rehabilitation plan able to be adjusted or modified if required.

Our results show ACLR patients in NZ receive a low dosage of physiotherapy treatment following surgery, with less than 12 treatments over 185 days. Previous retrospective studies have shown community-based ACLR patients can receive 15-58 treatments over 127-175 days (Christensen et al., 2017; Dempsey et al., 2019; Miller et al., 2017). The large range of physiotherapy treatment reflects the lack of a consensus regarding an optimal number of physiotherapy treatment following ACLR (Walker et al., 2020). While no optimal number of physiotherapy treatment exists that can be applied to all ACLR patients, the number of treatments required by each patient will be a product of the clients post-operative goals and individual progress through their rehabilitation programme. Following ACLR, a fortnightly review with the treating physiotherapist is suggested as the minimum requirement (Filbay & Grindem, 2019), and if rehabilitation lasts the recommended 9-12 months (van Melick et al., 2016), then the minimum number of post-ACLR physiotherapy treatments would be 18-24. Ultimately, the optimal number of physiotherapy treatments for each patient will be the number of treatments the patient requires to achieve their post-operative goals.

The temporal utilisation of a limited number of physiotherapy treatments following ACLR could also influence the duration of rehabilitation. Patients in the current study received 79% of post-ACLR physiotherapy treatments within six months of surgery – a finding consistent with a recent database analysis of over 11,000 ACLR patients that reported 90% of post-ACLR physiotherapy treatments were received within four months of surgery (Burroughs et al., 2021). If the majority of allocated treatments are utilised within a short timeframe after surgery, then the premature cessation of rehabilitation may be decided by the allocated number of treatments rather than the achievement of patient goals.

For almost 60% of subjects in the current study, post-ACLR physiotherapy treatment lasted less than six months, with physiotherapy lasting at least nine months for only a quarter of subjects. Although time-based rehabilitation following ACLR has now been succeeded by criterion-based rehabilitation (Meredith et al., 2020), time from surgery

is still the most considered factor when assessing a RTS (Burgi et al., 2019). Few ACLR patients achieve recommended criteria to resume pre-injury activities within nine months of surgery (Herbst et al., 2015; Toole et al., 2017; Welling et al., 2018), and a return to pre-injury activities before nine months significantly increases the risk of re-injury (Beischer et al., 2020; Bodkin et al., 2022; Grindem et al., 2016). The risk of re-injury following ACLR is also highest in the first 6-12 months of a return to pre-injury activities (Paterno et al., 2012; Webster & Feller, 2016). Therefore, physiotherapist treatment and oversight of rehabilitation from 7-12 months after ACLR may help reduce the risk of ACL re-injury at a time when most patients are considering returning to pre-injury activities.

The final phase of ACLR rehabilitation typically involves a resumption of functional activities, sport-specific training, and a graduated return to pre-injury sports (Buckthorpe, 2019), with most patients expecting a return to pre-injury activities between 6-12 months after surgery (Armento et al., 2020; Feucht et al., 2016). Subjects in the current study received on average less than two physiotherapy treatments between 7-12 months after ACLR, with 58% of subjects receiving no physiotherapy treatment during this time. Therefore, our results suggest NZ ACLR patients are undertaking end-stage rehabilitation without adequate professional oversight (Ebert et al., 2019; Filbay & Grindem, 2019). Low numbers of physiotherapy treatments between 7-12 months could reflect increased self-management (Ebert et al., 2019), decreased patient compliance (Risberg et al., 2016), a lack of physiotherapist skill and knowledge to manage an ACLR patient through the RTS phase (Walker et al., 2020), or the use of non-physiotherapy providers for rehabilitation guidance (Walker et al., 2021).

Multiple factors likely contribute to ACLR patients receiving a low dosage of physiotherapy treatment, including low patient motivation to complete rehabilitation (Thorstensson et al., 2009), a lack of patient education regarding post-ACLR rehabilitation (Cailliez et al., 2012), or a lack of surgeon endorsement of rehabilitation (Ebert et al., 2019). Patients report frustration and disappointment with a physiotherapists ability to manage late-stage ACLR rehabilitation (Walker et al., 2022), which could lead to patients prematurely disengaging in physiotherapy, resulting in a low number of treatments.

From a NZ-specific perspective, the provider co-payment, which can be up to $50 per treatment, for a private physiotherapy treatment, likely represents a significant barrier to an ACLR patient receiving the recommended dosage of physiotherapy following surgery. The limits placed on the number of physiotherapy treatments for an ACL injury by ACC have also potentially contributed to low numbers of treatments in the current study. The physiotherapist must submit a request to ACC for funding of additional treatments by providing their clinical records and a completed ACC32 form, which includes details regarding the patients current condition, how the current condition is linked to the covered injury, and a plan for the additional treatments. The request is then clinically assessed by ACC, with a subsequent decision issued to either approve or decline the request. This prior approval process represents a barrier to receiving additional physiotherapy treatments, as a decision to decline additional funding results in the patient being liable for the full cost of any further physiotherapy treatment, further compounding any financial burden on the patient. Other potential factors preventing engagement in physiotherapy following ACLR include patient-specific barriers (health literacy/understanding of the condition, cultural beliefs, socio-economic status), provider-specific barriers (patient interactions), and healthcare system barriers (waiting times, location of services, involvement of multiple providers) (See section 2.6.2).

A strength of the current study is the large number of subjects, which provides a level of statistical robustness. However, large cohorts increase the likelihood of significant results, even if those results may not be clinically relevant (Senorski, Svantesson, Baldari, et al., 2019). We used deterministic linkage to match two large, separate data sets, which can produce false negative links due to missing data and erroneous entries (Zhu et al., 2015). The retrospective design, while allowing a large cohort, prevents any causal links being established. ACC clients with an ACL injury may have more than one knee claim related to their ACL injury. Therefore, we cannot rule out the possibility of subjects receiving post-ACLR physiotherapy treatment under a knee claim that the ACLR was not funded under. However, this scenario is unlikely to apply to a large number of subjects, as ACC processes are designed to ensure all entitlements are funded under the correct claim. By choosing to use PROM data from the NZ ACL Registry, there was no control over the outcome measures used, and other PROMs

may be more appropriate measures to assess patient outcomes within two years of ACLR. The International Knee Documentation Committee (IKDC) form is a more useful tool to evaluate patients in the first year after ACLR (van Meer et al., 2013) and the Tegner Activity scale (TAS) is recommended when assessing activity levels in ACLR patients, particularly in conjunction with the IKDC (Wera et al., 2014).

4.7 Conclusions

Physiotherapy treatment improves subjective patient-reported outcomes following ACLR in the first 12 months after surgery, although the effect of physiotherapy treatment on activity levels is less certain. The majority of patients report acceptable symptoms and function at two years following ACLR, which is in contradiction to a low rate of return to pre-injury activity levels. Patients undergoing ACLR in NZ receive a low dosage of physiotherapy treatment following surgery. The optimal number of physiotherapy treatments following ACLR remains unclear and is likely dependent on multiple factors. A well-controlled prognostic study examining the effects of various quantities of physiotherapy treatment on outcomes following ACLR is warranted. However, ethical issues would likely render the undertaking of such a study challenging. Future prospective research on outcomes following ACLR should consider the appropriateness of the outcome measures used and how the demographics of the cohort might influence any findings.

Chapter 5

Current Perspectives of New Zealand Physiotherapists on Rehabilitation and Return to Sport Following Anterior Cruciate Ligament Reconstruction

This chapter comprises the following manuscript:

Fausett, W., Reid, D., & Larmer, P. (2022). Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport following anterior cruciate ligament reconstruction: A survey. *Physical Therapy in Sport*, *53*, 166-172. doi:10.1016/j.ptsp.2021.10.012

To maintain consistency of style throughout the thesis, the manuscript is presented here in a format that differs slightly to the published article (Appendix D).

5.1 Preface

Previous chapters have established that NZ ACLR patients receive a low dosage of physiotherapy treatment following ACLR, and physiotherapy treatment can influence a patients perception of their knee following surgery. However, the optimal dosage of post-ACLR physiotherapy treatment remains unclear. Multiple factors likely combine to influence the dosage of physiotherapy treatment ACLR patients receive. The perspectives of the providers who deliver ACLR rehabilitation around the world offer insights into variables that may influence the dosage of post-ACLR physiotherapy treatment. The thoughts and perspectives of NZ physiotherapists regarding ACLR rehabilitation are currently unknown. Therefore, this study is a survey of NZ physiotherapists on their beliefs and practices regarding rehabilitation and RTS following ACLR, with the aim of gaining insights into how physiotherapy practice in NZ may influence the dosage of treatment a patient receives.

5.2 Abstract

Objective: To investigate the clinical beliefs and practices of New Zealand physiotherapists regarding pre- and post-surgical rehabilitation and return to sport (RTS) criteria following anterior cruciate ligament reconstruction (ACLR).

Design: Online cross-sectional survey.

Methods: A survey was adapted from a previously published survey and disseminated to New Zealand physiotherapists who were considered more likely to be involved in post-ACLR rehabilitation.

Results: The number of completed surveys was 318. Most physiotherapists (85%) preferred to first consult patients within 14 days of ACLR. In the first six weeks following ACLR, 89% of physiotherapists see patients at least once per week. Between 3- and 6-months post-ACLR, 76% of physiotherapists see patients at least once a fortnight. Pre-operative rehabilitation and post-operative rehabilitation exceeding six months are considered essential or important to patient outcomes by over 95% of physiotherapists. While 63% of physiotherapists support RTS 9-12 months after ACLR, 11% permit RTS within 6-9 months of surgery. Common RTS considerations include functional capacity, movement quality during functional tasks, time from ACLR, and knee strength.

Conclusion: The survey revealed variability in the beliefs and practices of NZ physiotherapists regarding post-ACLR rehabilitation, and these beliefs and practices are at times inconsistent with best practice recommendations.

5.3 Introduction

Injury to the anterior cruciate ligament (ACL) of the knee typically occurs during sporting activities involving cutting, landing, and pivoting movements (Renström, 2013). Management of an ACL injury usually follows one of two pathways: 1) post-injury rehabilitation, followed by early surgical ACL reconstruction (ACLR) and post-surgical rehabilitation, or 2) post-injury rehabilitation, with the option of delayed ACLR if clinically indicated (Beynnon, Johnson, et al., 2005). The goals of ACLR are to facilitate a safe and sustainable return to pre-injury activities and prevent secondary

knee changes such as osteoarthritis, although recent research does not support these outcomes for a significant number of patients (Ardern et al., 2014; Harris et al., 2014). Despite no clear benefit of surgical over conservative management (Frobell et al., 2013; Wellsandt et al., 2018), annual rates of ACLR in certain populations have increased by up to 40% in recent years (Abram et al., 2020; Herzog et al., 2018; Zbrojkiewicz et al., 2018).

Independent of the treatment pathway chosen following ACL injury, rehabilitation is a critical factor that can influence short- and long-term patient outcomes (van Melick et al., 2016). Rehabilitation for ACLR includes pre-operative rehabilitation, followed by criterion-based post-operative rehabilitation, and a graduated return to pre-injury activities (Grindem, Wellsandt, et al., 2018). Pre-ACLR rehabilitation aims to eliminate any knee joint effusion, restore range of motion, and improve quadriceps strength (Filbay & Grindem, 2019; van Melick et al., 2016). The goals of post-ACLR rehabilitation are to restore neuromuscular function and modify any pre-injury risk factors that may increase the risk of subsequent ACL injury (Adams et al., 2012). While the effectiveness of rehabilitation following ACLR is well accepted (Lobb et al., 2012), there remains little consensus as to the optimal components of the rehabilitation program (Meredith et al., 2020). While clinical practice guidelines for post-ACL rehabilitation do exist, their usefulness in clinical practice may be limited due to low external validity (Andrade et al., 2019).

The annual incidence of ACLR in New Zealand (NZ) has increased by 58% since 2005 (Sutherland et al., 2019), and the annual cost of ACLR surgeries in NZ exceeds $25 million dollars (ACC, 2018a). Physiotherapists are key health professionals who manage pre- and post-ACLR rehabilitation (Filbay & Grindem, 2019); particularly so in the NZ context, where private practice-based physiotherapists oversee the significant majority of pre- and post-ACLR rehabilitation (See section 2.6.2). However, due to an underutilisation of physiotherapy services following surgery, patients undergoing ACLR in NZ may not be receiving an appropriate dosage of rehabilitation (See section 2.6.2).

There is considerable variability amongst therapists in beliefs and clinical practices regarding ACLR rehabilitation, including activity and exercise progression, knee strength testing, return to sport (RTS) timeframes, and frequency of treatment

(Dingenen et al., 2021; Ebert et al., 2019; Greenberg et al., 2018). Although physiotherapists are the main providers of post-ACLR rehabilitation in NZ (ACC, 2018c), the beliefs and practices of NZ physiotherapists regarding rehabilitation following ACLR are currently unknown. Therefore, the aim of the current study was to investigate practice beliefs of NZ physiotherapists regarding pre- and post-surgical rehabilitation and RTS criteria following ACLR.

5.4 Methods

An online survey consisting of 14 questions was utilised to survey NZ physiotherapists. The survey was adapted from a previously published survey of Australian therapists involved in ACLR rehabilitation (Ebert et al., 2019), with permission to replicate the survey granted by the lead author. The survey questions and possible responses are shown in Table 1. There were two minor changes to the original survey. Question three regarding which state/territory the provider practiced in was removed, as this was not applicable to the NZ population. In the original survey, participants could select as many options as applicable for questions 14 and 15. For technical reasons, participants could only select one option for those questions in the current survey (questions 13 and 14 in the current study). All other questions in the current survey were duplicated from the original study.

The survey was available for completion via an online platform (SurveyMonkey) between April 23rd 2020 and June 31st 2020. The survey was anonymous, which was clearly stated in the information section, with no personal participant data collected. Participants were required to self-identify as NZ registered physiotherapists with an up-to-date annual practicing certificate who were currently treating, or had previously treated, a patient who had undergone ACLR (Appendix L). If a participant did not self-identify with the above criteria, they were not granted access to the survey. No data was collected from participants regarding demographics, number of years practicing, qualifications, or location of practice.

An email invitation to complete the survey was sent to members of two Special Interest sub-groups of Physiotherapy New Zealand – New Zealand Manipulative Physiotherapists Association (NZMPA) and Sport and Exercise Physiotherapy New Zealand (SEPNZ). Members of these groups were considered more likely to be, or have

been, actively involved in the treatment of patients who had undergone ACLR. During the survey period, the survey was also promoted within the NZMPA and SEPNZ groups on a social media platform (Facebook) to increase survey exposure. In an effort to maximise response rates, participants had the option of entering a draw to win a gift card following completion of the survey.

After survey closure, group and individual responses were exported to Microsoft Excel format for examination. A descriptive analysis of the data was performed using SPSS (IBM SPSS Statistics V.26), with the number and percentage of respondents for each answer option calculated. Respondents could select an 'other (please specify)' option for questions 4, 5, 12, 13, and 14. Individual responses for each 'other (please specify)' option were analysed, and if considered appropriate, the response was removed from the 'other (please specify)' option and included in the most suitable answer option for that question.

5.5 Results

The number of completed surveys was 318, with all questions answered by all respondents. At the time the survey was available for completion, there were 192 members of NZMPA and 890 members of SEPNZ, for an estimated response rate of 29.3% (318/1082). The number of responses and percentages for each question are presented in Table 5.1. Almost 93% respondents identified their area of expertise as treating all musculoskeletal conditions, with over 90% of respondents treating 20 or less ACLR patients per year.

Table 5.1

Questions and responses (n, %) for each item from the anonymous survey.

Q1 What is your primary area of expertise for the purpose of this survey?		
All musculoskeletal conditions	295	93.0%
Primarily lower limb	9	2.8%
Primarily upper limb	2	0.6%
Other sub-specialty, but I still see some ACLR patients	11	3.5%
Other (please specify)	1	0.3%
Q2 Approximately, how many ACLR patients would you see per year?		
1-5	166	52.4%
6-20	131	41.3%
21-50	18	5.7%
>51	3	0.9%
Q3 At what post-operative time-point do you encourage your patient to be seen by you after their ACLR surgery?		
Within the first 1-4 days after surgery.	48	15.1%
Within the first 7 days after surgery.	133	41.9%
Between 1 and 2 weeks after surgery.	90	28.4%
After being cleared by their surgeon.	46	14.5%
When they feel ready to start, though I do not recommend a specific (or ideal) time.	1	0.3%
Q4 How often would you like to see your ACLR patient for supervised rehabilitation, within the first 6 weeks post-surgery?		
Twice per week.	160	50.3%
Once per week.	122	38.3%
Once every two weeks.	9	2.8%
Less frequently, if possible, with a focus on home-based exercises and periodic review.	5	2.5%
Other (please specify)		
• Dependent on patients progress, engagement, pre-injury activity level, financial status.	10	3.1%
• 1-2 x week.	9	2.8%
• 3 x week.	3	0.9%
Q5 Between 3- and 6-months post-surgery, how often would you like to see your ACLR		

patient within your practice?		
Twice per week.	26	8.2%
Once per week.	88	27.7%
Once every two weeks.	128	40.3%
Less frequently, if possible, with a focus on home-based exercises and periodic review.	65	20.4%
Other (please specify)		
• Dependent on patients progress.	6	1.9%
• Every 1-2 weeks.	3	0.9%
Q6 How important do you think 'pre-operative rehabilitation' is to post-operative patient outcome?		
Essential	199	62.8%
Important	116	36.9%
Not important	1	0.3%
No view or opinion	2	0.6%
Q7 How important do you think 'post-operative rehabilitation' is to overall patient outcome within the first 6 weeks post-surgery?		
Essential	247	77.9%
Important	70	22.1%
Not important	1	0.3%
No view or opinion	0	0%
Q8 How important do you think 'post-operative rehabilitation' is to overall patient outcome within 6 weeks to 3 months post-surgery?		
Essential	276	86.8%
Important	41	12.9%
Not important	1	0.3%
No view or opinion	0	0%
Q9 How important do you think 'post-operative rehabilitation' is to overall patient outcome within 3-6 months post-surgery?		
Essential	230	72.3%
Important	83	26.1%
Not important	3	0.9%
No view or opinion	2	0.6%
Q10 How important do you think 'post-operative rehabilitation' is to overall patient outcome from 6 months post-surgery onwards?		

Essential	144	45.3%
Important	157	49.4%
Not important	13	4.1%
No view or opinion	4	1.3%
Q11 Providing you are satisfied with their progress and physical capacity, what time do you typically permit a patient to return to sport (including rugby/league, soccer, netball, touch rugby etc.)?		
6-9 months.	35	11.0%
9-12 months.	201	63.2%
12-18 months.	77	24.2%
≥18 months.	4	1.3%
I tell them they should not return to higher demand sports (e.g. rugby/league, soccer, netball).	1	0.3%
Q12 Given the aforementioned high demand sports, what factors do you personally consider before 'clearing' a patient to return to their sport? (Check all that apply)		
Time from surgery.	239	75.2%
Age of the patient.	141	44.3%
Knee Range of Movement and/or Laxity.	225	70.8%
Patient-reported Outcome Questionnaires.	167	52.5%
Psychological readiness (e.g. confidence, anxiety).	284	89.3%
Knee Strength.	287	90.3%
Functional capacity (e.g. jump and/or hop tests).	312	98.1%
Lower limb and trunk mechanics during jumping/landing task.	294	92.5%
Side-to-side differences in muscular size (i.e. thigh girth).	163	51.3%
Other (please specify)		
• Return to Sport tests/Sport specific tasks.	30	9.4%
• Proprioception/Agility.	8	2.5%
• Cardiovascular fitness.	4	1.3%
• Surgeon clearance.	3	0.9%
• Symptoms eg pain, swelling.	3	0.9%
Q13 If you consider 'knee strength' to be important prior to clearing a patient to return to their sport, how do you evaluate this?		
I use manual muscle testing methods.	51	16.0%
I use handheld dynamometry.	51	16.0%

I use an isokinetic dynamometer.	20	6.3%
I extrapolate/estimate knee strength from other measures such as hop capacity.	115	36.2%
I feel strength is important, but do not have access to necessary equipment (and/or do not feel manual testing methods are accurate enough) so I refer on to someone who can provide this evaluation for me.	24	7.6%
I do not consider these tests that important.	5	1.6%
Other (please specify)		
• Gym based/Repetition Maximum testing.	78	24.5%
Q14 If you consider 'lower limb functional capacity' to be important prior to clearing a patient to return to their sport, how do you evaluate this?		
Star excursion and/or Y-balance test.	12	3.8%
Single limb vertical hop.	5	1.6%
Single limb hop for distance.	20	6.3%
6m timed hop test.	2	0.6%
Triple hop for distance.	16	5.0%
Triple crossover hop for distance.	8	2.5%
A hop test battery (including ≥2 of the 6m timed and single, triple hop and triple crossover hops for distance).	214	67.3%
I do not consider these tests that important.	3	0.9%
Other (please specify)		
• Combination of all the above.	27	8.5%
• Sport specific tasks.	9	2.8%
• Passive range of movement.	2	0.6%

Abbreviations: ACLR = anterior cruciate ligament reconstruction.

While 57% of respondents wished to see their patient within a week of ACLR, 28.4% of respondents preferred to wait until 7-14 days after surgery (Table 5.1). Within the first six weeks of ACLR, over 91% of respondents would see their patients 1-2 times per week. Between 3- and 6-months post-ACLR, 76.2% of respondents would see patients in the clinic at least once per fortnight, with over 20% preferring less frequent visits and a focus on home or gym-based exercises.

Almost all respondents consider rehabilitation essential or important to overall outcome from ACLR at all time points surveyed (Table 5.1). Between six weeks and three months was the period when the most respondents considered rehabilitation 'essential' (86.8%), compared to six months post-ACLR onwards when the least respondents considered rehabilitation 'essential' (45.3%).

Providing the patient had made satisfactory progress and displayed adequate physical capacity, 63.2% of respondents permitted RTS 9-12 months after ACLR (Table 5.1). Almost a quarter of respondents (24.2%) would wait 12-18 months after ACLR before supporting RTS, whereas 11% would allow RTS within 6-9 months of surgery. Functional capacity (98.1%), lower limb/trunk mechanics during functional tasks (92.5%), knee strength (90.3%), psychological readiness (89.3%), and time from surgery (75.2%) were the factors most commonly considered before permitting a patient to RTS after ACLR, with only 52.5% of respondents reporting the use of patient reported outcome measures to asses RTS readiness (Table 5.1).

To evaluate knee strength, 36.2% of respondents estimate strength via other means e.g. hop tests, while an equal number of respondents use manual muscle testing (MMT) or hand held dynamometry (HDD) (16%) (Table 5.1). Only 24.5% of respondents use gym-based repetition maximum (RM) testing i.e. 1-10 RM for squat, deadlift, single leg press, knee extension/hamstring curl machine, to assess knee strength when considering RTS. Although respondents could select only one option for question 13 regarding knee strength, the total number of responses for that question exceeds the total number of respondents. The reason for this discrepancy is a large number of respondents selected 'other (please specify)' and recorded multiple methods of assessing knee strength in their response. Accordingly, and where possible, responses from the 'other (please specify)' option were added to the

appropriate answer totals for question 13. To evaluate lower limb functional capacity, 67.3% of respondents use a hop test battery, 16% use only one hop test, and 3.8% use the star excursion balance test (SEBT) and/or Y-balance test (YBT) (Table 5.1).

5.6 Discussion

The aim of this study was to gain insights into the current beliefs and practices of NZ physiotherapists regarding rehabilitation and RTS following ACLR. We estimated a survey response rate of 29.3%. Previous surveys of therapists working with ACLR patients have been unable to calculate a response rate (Dingenen et al., 2021; Ebert et al., 2019; Greenberg et al., 2018); however, a recent online survey involving NZ physiotherapists reported a response rate of approximately 10% (Reid et al., 2020).

Successful rehabilitation following ACLR is challenging and should be performed by a clinician with experience in post-ACLR rehabilitation (Buckthorpe, 2019; Filbay & Grindem, 2019). Only 47.6% of respondents in the current study report treating more than six ACLR patients per year, which is less than Australian (74%) and United States (US) therapists (66.7%) (Ebert et al., 2019; Greenberg et al., 2018). Australia has higher rates of ACLR compared to NZ (Zbrojkiewicz et al., 2018), which could contribute to physiotherapists seeing more ACLR patients in that country. Although rates of ACLR in NZ are now similar to the US (Sutherland et al., 2019), this has not yet translated into NZ physiotherapists treating similar numbers of ACLR patients. Over 90% of respondents indicated they treat all musculoskeletal conditions, suggesting few NZ physiotherapists classify themselves as ‘specialists’, which may potentially limit exposure to ACLR patients.

Post-ACLR rehabilitation should commence immediately following surgery (Filbay & Grindem, 2019; van Melick et al., 2016). Only 57% of respondents in the current survey would see patients in the week following ACLR, which is consistent with Australian (53%) and Flemish (62%) therapists (Dingenen et al., 2021; Ebert et al., 2019). The reasons why a significant percentage of therapists across multiple populations do not commence rehabilitation within the first week of ACLR require further investigation, but could include surgeons not endorsing rehabilitation in the first week following surgery (Feller et al., 2002).

Almost 90% of respondents in the current study would see their patient 6-12 times within the first six weeks, and over 77% would see patients 6-24 times between three and six months, which are higher percentages than Australian therapists (82.1% and 58.7%) for the respective time periods (Ebert et al., 2019). It is not clear how frequent respondents would see their patients between six weeks and three months, or from six months onwards, as these periods were not surveyed. Therefore, the majority of respondents in the current survey would see their patients at least 12-36 times within the first six months of ACLR, which is similar to the number of physiotherapy treatments currently suggested following ACLR (Adams et al., 2012; Filbay & Grindem, 2019).

Physiotherapist-led rehabilitation prior to ACLR, and 9-12 months of structured rehabilitation post-ACLR, can optimise patient outcomes (Alshewaier et al., 2017; van Melick et al., 2016). Almost all respondents in the current study considered pre-operative rehabilitation essential or important to overall outcome following ACLR, which is similar to Australian therapists (Ebert et al., 2019). At least 94% of respondents considered rehabilitation essential or important to patient outcomes up to and exceeding six months post-surgery, again similar to Australian therapists (Ebert et al., 2019), but greater than US and Flemish therapists (Dingenen et al., 2021; Greenberg et al., 2018).

Our results suggest NZ physiotherapists are aware of the dosage (quantity and duration) of physiotherapy treatment necessary to achieve optimal patient outcomes – an awareness that does not seem to translate into clinical practice. A recent study showed patients undergoing ACLR in NZ receive an average of 8-12 physiotherapy treatments over an average duration of approximately five months following surgery (See sections 2.6.1 and 2.6.2). As such, there is a large discrepancy between the dosage of treatment physiotherapists in NZ believe they are providing following ACLR, and the actual dosage of physiotherapy treatment being provided. ACL rehabilitation in NZ is almost exclusively funded by the Accident Compensation Corporation (ACC), which is a government entity that administers a public insurance scheme that funds medical treatment and providing compensation following accidents (Flood, 2000). Up until 2019, ACC placed limits on the number of physiotherapy treatments providers could deliver without first seeking prior approval, which could represent a barrier to

patients receiving physiotherapy treatment following ACLR (See section 2.6.2). Other possible barriers to receiving the optimal dosage of physiotherapy treatment following ACLR could include economic constraints, decreased patient motivation to complete rehabilitation, decreased patient understanding of rehabilitation requirements, and a lack of surgeon endorsement of rehabilitation (Cailliez et al., 2012; Ebert et al., 2019; Ebert et al., 2019) (See section 2.6.2). It should be noted the optimal dosage of physiotherapy treatment following ACLR is yet to be established (van Melick et al., 2016; Walker et al., 2020). The overall dosage of physiotherapy treatment following ACLR will be dependent on the treatment plan, with adjustments made according to the progress of the individual patient (Filbay & Grindem, 2019; Wilk & Arrigo, 2017),

RTS within nine months following ACLR is associated with an increased risk of re-injury (Beischer et al., 2020; Grindem et al., 2016). Over 87% of respondents in the current study reported waiting at least nine months after ACLR before supporting a RTS, which is higher than Australian (77%), Flemish (73%), US (45%) and Brazilian (22% recommend ≥ 8 months) therapists (Aquino et al., 2021; Dingenen et al., 2021; Ebert et al., 2019; Greenberg et al., 2018). Only 11% of respondents would support a RTS between 6-9 months, which is less than Australian (22%), Flemish (25%), and US (38%) therapists (Dingenen et al., 2021; Ebert et al., 2019; Greenberg et al., 2018). Supervised rehabilitation after ACLR that exceeds 6 months is associated with increased knee strength, improved functional capacity, and greater limb symmetry (Ebert et al., 2018; Edwards et al., 2018; Królikowska, Sikorski, et al., 2018b) – factors that also decrease the risk of graft rupture and increase the likelihood of a successful RTS (Kyritsis et al., 2016; Meredith et al., 2020). Although criterion-based measures are now recommended over time-based measures following ACLR (Adams et al., 2012), time from surgery and duration of rehabilitation likely influence patient outcomes. Our results indicate the majority of NZ physiotherapists endorse a RTS timeframe consistent with current evidence, while also being more aware of the importance of 'time from surgery' when considering RTS following ACLR than overseas counterparts.

Physical capacity, movement quality, psychological readiness, and biological healing are factors recommended to consider when evaluating a patient for RTS following ACLR (Filbay & Grindem, 2019; van Melick et al., 2016). The factors NZ physiotherapists consider when evaluating a patient for RTS align with current

recommendations, and are also consistent with factors considered by Australian, Flemish, and Brazilian therapists (Aquino et al., 2021; Dingenen et al., 2021; Ebert et al., 2019). Successful RTS following ACLR includes achieving the pre-injury level of activity, as defined by the same type, frequency, intensity and quality of performance (Meredith et al., 2020). A multidisciplinary team, including the physiotherapist, should be involved in any RTS decision (Meredith et al., 2020). However, NZ physiotherapists may not be actively involved in patient management at the time of RTS, as the duration of physiotherapy treatment in NZ after ACLR does not often extend to the time-point where patients are potentially contemplating a RTS (See section 2.6.1).

Patient-reported outcomes measures (PROMs) are recommended to help quantify outcomes during ACLR rehabilitation (Dingenen & Gokeler, 2017; Lynch et al., 2015). However, just over half of respondents in the current study report using PROMs to assist with RTS decision making. These findings are consistent with previous surveys of physiotherapists report low use of PROMs during ACLR rehabilitation (Aquino et al., 2021; Ebert et al., 2019; Greenberg et al., 2018). Regular use of PROMs during ACLR, in conjunction with appropriate functional testing, can increase patient motivation and adherence throughout the rehabilitation period (Risberg et al., 2016). Therefore, the low use of PROMs by NZ physiotherapists may contribute to decreased patient motivation during ACLR rehabilitation, resulting in low utilisation of physiotherapy overall.

Just over one third of respondents report estimating knee strength from functional measures such as hop capacity, which is less than Australian therapists (48.9%) (Ebert et al., 2019). Caution should be used when using hop tests in this way, as results from functional tests do not always correlate with objective measures of knee strength (Toole et al., 2017), leading to a possible overestimation of knee strength. Manual muscle testing (MMT) and hand held dynamometry (HDD) were also commonly reported methods to evaluate knee strength; a finding consistent with US therapists (Greenberg et al., 2018) but less often than Australian therapists (Ebert et al., 2019). MMT and HDD require little resource, which likely contributes to their popularity, although their accuracy may be less than other methods (Bohannon, 2005; Sinacore et al., 2017). The reliability of gym-based repetition maximum (RM) tests are similar to MMT and HDD (Sinacore et al., 2017). However, only one in four respondents in the

current study report using gym-based RM testing to evaluate knee strength, which is similar to US therapists (Greenberg et al., 2018). Isokinetic evaluation of knee strength remains the gold standard but utilisation of this by NZ and Australian therapists is low, likely due to cost and availability (Ebert et al., 2019). Overall, the methods reportedly used by the majority of NZ physiotherapists to evaluate knee strength after ACLR could lead to an inaccurate assessment of strength. An incorrect estimation of knee strength could lead to an insufficient rehabilitation stimulus to promote functional improvement, the prescription of rehabilitation exercises that exceed the patients true functional ability, or a premature return to pre-injury activities (Beischer et al., 2018; Filbay & Grindem, 2019). Given the positive relationship between knee strength and patient outcomes following ACLR (Arhos et al., 2020; Cristiani, Mikkelsen, et al., 2020), there appears considerable scope for improvement in the assessment of knee strength by NZ physiotherapists.

Approximately 75% of respondents in the current study reported using a hop test battery to evaluate lower limb functional capacity for RTS, which compares favourably to Australian (84.3%) and US therapists (79.4%) (Ebert et al., 2019; Greenberg et al., 2018). Hop tests are commonly used in the clinic setting, as they are relatively easy to administer, and produce valid, reliable results (Reinke et al., 2011). A hop test battery should be utilised when considering a RTS following ACLR (Ardern, Glasgow, et al., 2016; van Melick et al., 2016), and greater performance during hop tests can be associated with improved patient outcomes (Edwards et al., 2018; Kyritsis et al., 2016). Measuring only quantitative performance during hop tests maybe insufficient to fully assess knee function after ACLR (Kotsifaki et al., 2020; Nagai et al., 2020). A 'quality' assessment of movement performance during hop tests is recommended (Davies et al., 2020), as meeting RTS criterion on a quality measure is associated with a lower second ACL injury rate (van Melick et al., 2022). Of note is the 25% of respondents in the current study who report not using a hop test battery. Using only one hop test to asses lower limb functional capacity could result in a sub-optimal assessment of physical performance and compromise RTS, as no single hop test can consistently predict RTS or risk of re-injury (Davies et al., 2020).

Only 12.3% of respondents report using the star excursion balance test (SEBT) and/or Y-balance test (YBT) to assess functional capacity when considering RTS following

ACLR, compared to 62.8% and 48.8% of Australian and US therapists respectively (Ebert et al., 2019; Greenberg et al., 2018). As performance on the SEBT in ACLR patients at the time of RTS has been shown to be worse compared to uninjured controls (Clagg et al., 2015), increased utilisation of balance tests by NZ physiotherapists when evaluating lower limb function may be indicated. The reasons for the low utilisation of balance tests by NZ physiotherapists compared to overseas counterparts are not entirely clear. In contrast to the original survey of Ebert et al, respondents were limited to one selection for the question regarding methods to assess lower limb functional capacity. Therefore, the low reported usage of balance tests may be an underestimation, as more respondents could have selected hop tests as they considered these more important, despite in fact using balance tests to assess functional capacity.

A number of limitations with the current study can be identified. Despite all NZMPA and SEPNZ members being notified of the survey, the estimated response rate was approximately 30%. A low survey response rate can introduce bias and compromise the validity of the results. Due to unrestricted access to the survey via social media, we cannot exclude the possibility NZ physiotherapists who are non-members of NZMPA or SEPNZ completed the survey, although this is unlikely to be a significant number. Although there are over 4000 registered physiotherapists in NZ, we limited promotion of the survey to specific groups of physiotherapists in NZ, which potentially constrained both the number and diversity of responses. In the current study, respondents were restricted to NZ registered physiotherapists, but in the original study the survey was sent to members of the Australian Physiotherapy Association and Exercise and Sport Science Australia, as members of both groups are involved in delivering post-ACLR rehabilitation (Ebert et al., 2019). Different training between the professions and diverse practice beliefs between the study populations could have contributed to discrepancies between the results. It is possible some respondents in the current study answered questions from a 'what is *best* clinical practice' perspective, rather than 'what is *actual* clinical practice' perspective, which could explain some of the variability in the results. No data was collected regarding participant demographics and practice variables (number of years practicing, qualifications, location of practice etc.), and the absence of such information may limit

the overall generalisability of the results. Participant anonymity is required for ethical approval; however, the lack of a participant specific log-in could, in theory, permit multiple responses from the same participant. Although SurveyMonkey will not allow the survey to be completed on multiple occasions from the same computer and internet browser, it is not possible to say whether participants accessed the survey multiple times via different internet browsers.

5.7 Conclusions

Results of this survey revealed NZ physiotherapists have varied beliefs and practices regarding rehabilitation and RTS following ACLR. The need for pre-and post-ACLR rehabilitation is well recognised amongst physiotherapists, and although the majority of respondents report beliefs consistent with current recommendations, it is not clear if those beliefs are consistent with clinical practice. The commencement of post-ACLR rehabilitation and frequency of patient visits is variable, with multiple factors likely influencing the overall dosage of physiotherapy treatment. Areas for future research include exploring discrepancies between therapist beliefs regarding ACLR rehabilitation and objective treatment data, investigating barriers to delays in commencing rehabilitation following ACLR, increasing the usability of clinical practice guidelines, and improving access to appropriate methods to assess knee strength and RTS testing following ACLR.

Chapter 6

Discussion

6.1 Aims and Findings of this Thesis

The overall aims of this thesis were to:

i. determine the dosage of physiotherapy treatment received by patient undergoing ACLR in NZ.
ii. systematically review the existing literature that had investigated the effects of the quantity and duration of physiotherapy treatment on patient outcomes following primary ACLR.
iii. determine the relationship between the quantity of physiotherapy treatment and 2-year patient-reported outcomes following ACLR in NZ.
iv. investigate beliefs and practice of New Zealand physiotherapists regarding pre- and post-surgical rehabilitation and return to sport criteria following ACLR.

A summary of findings is outlined in Table 6.1:

Table 6.1

Summarised aims of the thesis, knowledge prior to conducting this research, and what was added by the findings of this thesis.

Chapter	Aims	What was known	What this research adds
Chapter 2 – Physiotherapy treatment in NZ following anterior cruciate ligament reconstruction.			
2	Undertake a retrospective review of a three-year period of ACC claim data to determine the dosage (quantity and duration) of physiotherapy treatment following ACL injury, and during pre- and post-ACLR rehabilitation, in New Zealand.	Physiotherapists have the requisite knowledge and skills to manage the functional component of ACLR rehabilitation. Supervised physiotherapy treatment is recommended after ACLR and improves outcomes after ACLR. There is no consensus regarding the optimal dosage of physiotherapy treatment following ACLR.	The average number of physiotherapy treatments in the 12 months prior to ACLR was 7-8, depending on the delay to surgery. The average number of physiotherapy treatments in the 12 months following ACLR was 10-12, over an average of 143-161 days, depending on the delay to surgery. For conservatively managed ACL injuries, the average number of physiotherapy treatments in the 12 months following injury was 8, over an average duration of 90 days.

Chapter	Aims	What was known	What this research adds
Chapter 3 – The relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following primary anterior cruciate ligament reconstruction.			
3	Systematically review the existing literature that had investigated the effects of the quantity and duration of physiotherapy treatment on patient outcomes following primary ACLR.	Physiotherapist-led rehabilitation following ACLR can improve patient outcomes. The optimal quantity and duration of physiotherapy treatment following ACLR is currently unknown.	There are no controlled trials that have specifically investigated the effects of the quantity and duration of physiotherapy treatment on patient outcomes following primary anterior cruciate ligament reconstruction. Based on evidence of variable methodological quality, a clear relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following ACLR could not be established.

Chapter	Aims	What was known	What this research adds
Chapter 4 – Patient acceptance of knee symptoms and function after anterior cruciate ligament reconstruction is improved by physiotherapy treatment.			
4a	Quantify the dosage (quantity and duration) of pre- and post-operative physiotherapy treatment for patients undergoing ACLR in New Zealand.	Patients undergoing ACLR in New Zealand may not be receiving the recommended dosage of physiotherapy treatment following surgery.	22% of patients did not receive physiotherapy treatment in the 12 months prior to ACLR. The average number of physiotherapy treatments between 0-6, 7-12, and 13-24 months post-ACLR was 9.2, 1.9, and 0.6 respectively. The average duration of physiotherapy treatment following ACLR was 185 days.
4b	Determine the relationship between the quantity of physiotherapy treatment and 2-year patient-reported outcomes (KOOS[4], MARS) following ACLR in New Zealand.	Patient-reported outcomes typically improve following ACLR. PASS scores may better facilitate interpretation of patient-reported outcomes scores. The influence of the dosage of physiotherapy treatment on patient-reported outcomes following ACLR is not clear.	The quantity of physiotherapy treatment did not influence patient-reported outcomes following ACLR. Physiotherapy treatment following ACLR was independently associated with an increased likelihood of achieving a KOOS[4] PASS score at 6 and 12 months after surgery, but not at 24 months post-surgery. Physiotherapy treatment following ACLR was not associated with an increased likelihood of achieving a normative MARS score in the 24 months after surgery.

Chapter	Aims	What was known	What this research adds
Chapter 5 – Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport following anterior cruciate ligament reconstruction.			
5	Investigate beliefs and practices of New Zealand physiotherapists regarding pre- and post-surgical rehabilitation and return to sport criteria following ACLR.	There is no consensus regarding the components of a rehabilitation programme following ACL injury and ACLR. Physiotherapists are primary providers of rehabilitation following ACL injury and ACLR in NZ. There is variability in the beliefs and practices of physiotherapists regarding rehabilitation following ACL injury and ACLR in other countries.	There is variability in the beliefs and practices of New Zealand physiotherapists regarding ACLR rehabilitation, and those beliefs and practices are at times inconsistent with best-practice recommendations. The beliefs and practices of New Zealand physiotherapists regarding ACLR rehabilitation are inconsistent with the actual quantity and duration of physiotherapy treatment ACLR patients are receiving. Low numbers of NZ physiotherapists report using valid and reliable measures to assess patient status and outcomes following ACLR.

6.2 The Perspective and Content of This Discussion

During analysis of this thesis, the following themes emerged:

(i) the low dosage of physiotherapy treatment received by NZ ACLR patients.
(ii) the lack of a clear relationship between that dosage of physiotherapy treatment and patient-reported outcomes following ACLR.
(iii) how a lack of regular outcome assessment following ACLR potentially impacts the rehabilitation process.
(iv) there are discrepancies between NZ physiotherapist beliefs and practices, and actual clinical practice following ACLR.

The first section of this discussion explores the quantity of physiotherapy treatment prior to ACLR, and the quantity and duration of physiotherapy treatment following ACLR. Factors that have potentially contributed to the dosages of treatment during these periods are discussed with reference to the results of chapters two through five.

The second section discusses the relationship between the quantity of physiotherapy treatment received and patient-reported outcomes following ACLR. How the outcome measures utilised in the chapter four study may have influenced the results is also explored.

In the third section, the implications of the findings of this thesis for physiotherapy management of ACLR in NZ are discussed. The potential impacts of recent changes within the ACC scheme, which aim to address some of the issues borne out of this thesis, are highlighted.

Lastly, the impact of the findings of this thesis on physiotherapy practice during ACLR rehabilitation in NZ is discussed, with suggestions for future-state physiotherapeutic management of ACLR rehabilitation in NZ made.

6.3 Physiotherapy Treatment and Anterior Cruciate Ligament Reconstruction in New Zealand

6.3.1 Quantity of Physiotherapy

Physiotherapy Treatment Prior to Anterior Cruciate Ligament Reconstruction

The results from chapters two and four show the NZ ACLR patients receive between five and seven physiotherapy treatments in the 12 months prior to surgery, which is less than what previous research suggests is optimal (Alshewaier et al., 2017; Carter et al., 2020; Eitzen et al., 2010; Failla et al., 2016). Furthermore, chapter two and four results also show up to a quarter of NZ ACLR patients do not receive any physiotherapy treatment prior to surgery. With an average of 4-6 months from ACL injury to ACLR (See section 2.5.3) (New Zealand ACL Registry, 2021), there is more than sufficient time for NZ ACLR patients to engage in physiotherapist-led rehabilitation prior to surgery (Alshewaier et al., 2017). Although NZ Orthopaedic endorsement of pre-ACLR rehabilitation is unknown, almost 40% of Orthopaedic surgeons in Australia do not consider pre-ACLR rehabilitation is important (Ebert et al., 2019). Therefore, a lack of surgeon endorsement potentially influences a patients utilisation of physiotherapy services prior to surgery (Walker et al., 2022). Other barriers that may reduce patient engagement in pre-ACLR rehabilitation are the cost of private physiotherapy treatment in NZ and a lack of patient education regarding the need for rehabilitation following ACL injury (See section 2.6.2) (Cailliez et al., 2012). The net result is a low dosage, or complete absence, of pre-surgical rehabilitation for NZ ACLR patients that may contribute to a sub-optimal post-operative outcome.

A significant percentage of ACL-injured patients who undertake an appropriate period of rehabilitation are able to return to pre-injury activities without the need for ACLR, (Kaplan, 2011; Thoma et al., 2019). Therefore, physiotherapy treatment in the initial period after ACL injury can potentially alter a patients management pathway. A patients ability to cope with an ACL-deficient knee can, in some cases, be determined by a screening examination, which can include both objective data e.g. hop tests, and subjective data e.g. PROMs (Fitzgerald et al., 2000). Therefore, injury management decisions are dependent on having valid and reliable objective data to base any management decision on. Results from chapter five show only 52% of NZ

physiotherapists use validated PROMs to assess a patients status following ACLR, which is consistent with previous research showing less than 50% of physiotherapists use outcomes measures in practice (Jette et al., 2009). Although chapter five results show the majority of NZ physiotherapists use hop tests to estimate knee strength and assess lower limb functional capacity, hop tests have not been shown to consistently predict successful outcomes following ACLR (Davies et al., 2020). Hop tests should not be considered a measure of knee muscle strength following ACLR, as compensation strategies may be adopted, and hop tests are more reflective of total lower limb function than a specific measure of knee muscle performance (Berg et al., 2022). There is also a poor association between hop test performance and PROMs following ACLR (Losciale et al., 2020). Overall, the low percentage of NZ physiotherapists utilising PROMs, and high numbers using inappropriate methods to evaluate patient functional ability, potentially limits the identification of patients in NZ who may be able to cope with an ACL-deficient knee.

Physiotherapy Treatment Following Anterior Cruciate Ligament Reconstruction

The results from chapters two and four show NZ ACLR patients receive between 8-12 physiotherapy treatments in the 24 months following surgery. A minimum of 18-24 physiotherapy treatments may be necessary following ACLR (Filbay & Grindem, 2019; van Melick et al., 2016), with previous retrospective studies of community-based ACLR rehabilitation showing the number of treatments can range from less than 10 to more than 50 (Christensen et al., 2017; Dempsey et al., 2019; Miller et al., 2017; Walker et al., 2021; Walston & Barillas, 2021). The number of physiotherapy treatments following ACLR required to achieve an optimal outcome has not been established (Walker et al., 2020), with greater and lesser quantities of physiotherapy treatment following ACLR associated with both better and worse outcomes for a range of outcomes measures (Christensen et al., 2017; De Carlo & Sell, 1997; Feller et al., 2004; Han et al., 2015; Law et al., 2021; Miller et al., 2017). A recent umbrella review of 16 systematic reviews on ACLR rehabilitation was unable to determine the optimal quantity of rehabilitation following surgery due to a lack of meaningful data, and concluded structured in-person rehabilitation (14–36 physiotherapy visits) was generally not superior to structured home-based rehabilitation (3–17 physiotherapy visits) (Culvenor et al., 2022) – a finding consistent with multiple previous systematic

reviews on ACLR rehabilitation (Coppola & Collins, 2008; Gamble et al., 2021; Papalia et al., 2013).

Therefore, results from chapter two and four indicate NZ ACLR patients are receiving a quantity of physiotherapy treatment that previous research suggests is the equivalent of a home-based rehabilitation programme rather than a clinic-based, supervised programme. Within the previous literature there are significant discrepancies between the levels of supervision during rehabilitation (Darain et al., 2016), with all patients in most studies receiving some form of physiotherapist input during rehabilitation and very few studies including patients who received no physiotherapy input at all during ACLR rehabilitation. Such discrepancies, and the wide range of physiotherapy treatment dosages used in past research, have potentially contributed to the inability to determine an optimal number of physiotherapy treatments following ACLR.

6.3.2 Duration of Physiotherapy Treatment

The results from chapters two and four show NZ ACLR patients receive physiotherapy treatment for an average of 143-185 days following surgery. Nine to twelve months of criterion-based rehabilitation is recommended following ACLR (van Melick et al., 2016). However, as few controlled studies include an ACLR rehabilitation program lasting longer than six months (Dunphy et al., 2020), the recommended timeframe for ACLR rehabilitation is likely based on the following factors: (i) the increased re-injury risk following a RTS within nine months of ACLR (Grindem et al., 2016), (ii) few patients achieving the recommended functional criteria to RTS within nine months of ACLR (Arundale et al., 2017), (iii) restoration of quadriceps strength and neuromuscular control of the knee taking up to 12-24 months after surgery (Nagelli & Hewett, 2017). NZ ACLR patients typically receive physiotherapy treatment for less than six months following surgery, which suggests they are unlikely to achieve adequate knee strength and functional ability before resuming pre-injury activities, placing themselves at an increased risk of re-injury (Kyritsis et al., 2016). Time from surgery remains an important factor when considering a RTS after ACLR, (Burgi et al., 2019), which likely reflects the 1-2 years required for ACL graft maturation and the knee joint to return to biological homeostasis (Nagelli & Hewett, 2017).

Progression through traditional ACLR rehabilitation programmes was typically based on the time since surgery, with little regard for the patients functional ability (Shelbourne & Nitz, 1990). Recent years have seen a paradigm shift, with rehabilitation progressions now based on the patients ability to achieve pre-determined levels of strength and function (van Melick et al., 2016). Individual differences in biological healing, impairment resolution, neuromuscular control, functional ability, and psychological readiness have now seen the abandonment of purely time-based ACLR rehabilitation (Meredith et al., 2020). With this change in practice comes the realisation there is likely no singular duration of rehabilitation applicable to all ACLR patients.

Criterion-based progression through ACLR rehabilitation requires regular assessment of quadriceps and hamstring strength, functional ability using hop tests, and patient status using PROMs (van Melick et al., 2016). It would not be possible to assess a patient against a criterion measure of performance without objective data. However, results from chapter five show a low usage of PROMs, and a lack of valid methods used to assess lower limb strength, following ACLR by NZ physiotherapists. As such, NZ physiotherapists may not have adequate or appropriate information to reliably inform progressions through an ACLR rehabilitation programme.

6.3.3 What Might Influence the Dosage of Physiotherapy Treatment Following Anterior Cruciate Ligament Reconstruction in New Zealand?

Multiple factors potentially contribute to the low dosage of physiotherapy treatment following ACLR in NZ, including, but not limited to, the cost of physiotherapy treatment, the variations of funding and support within the ACC system, limitations in physiotherapist skills and knowledge, and the absence of regular patient assessment during rehabilitation.

Although ACC claims to meet treatment and rehabilitation costs for injuries caused by accidents in NZ, ACC's payment to providers for treatment costs may not meet the full cost of the treatment, resulting in the patient being responsible for a significant percentage their post-ACLR rehabilitation costs. Private physiotherapists in NZ often charge a co-payment per treatment, which may be up to $50. Therefore, results from chapters two and four indicate the average minimum cost to the NZ ACLR patient

receiving post-ACLR rehabilitation in a private setting could be up to $600. However, if a course of ACLR rehabilitation involves at least 18-24 physiotherapy treatments as recommended (Filbay & Grindem, 2019; van Melick et al., 2016), the direct cost to the patient will be approximately $900-$1200 over 9-12 months. If the patient is unable to work because of their ACL injury, they may be eligible for earnings-related compensation (ERC) from ACC. However, ERC is only paid at a rate of 80% of pre-injury earnings, compounding the financial burden on the patient. The patient may be entitled to receive fully-funded vocational rehabilitation (VR) from ACC, which often includes physiotherapist-led functional rehabilitation (ACC, 2021c). However, a patient's entitlement to VR only lasts as long as they are in receipt of ERC. Once the patient can substantially engage in their pre-injury work activities, their entitlement to ERC, and therefore VR, ceases. Results from chapter two show NZ ACLR patients received ERC for an average of 93-102 days, depending on the delay to surgery, following surgery. Therefore, the duration of fully funded ACLR rehabilitation in NZ is approximately three months, which is woefully inadequate to fully rehabilitate an ACLR patient. Clinical practice guidelines recommending not resuming sports or heavy physical activity within three months of ACLR (Filbay & Grindem, 2019; Meuffels et al., 2012).

A small number of private physiotherapists in NZ do not charge a co-payment for treatment, and a patient is free to choose which provider they engage with for their rehabilitation. ACLR patients in NZ can also seek physiotherapy treatment via the hospital-based public health system. However, access barriers (Goodyear-Smith & Ashton, 2019), cultural factors, including language barriers and institutional racism (Rahiri et al., 2018; Talamaivao et al., 2020), significant delays in receiving treatment, and resourcing constraints (Dunphy et al., 2022) within publicly funded healthcare contribute to private physiotherapists delivering the significant majority of rehabilitation for accident related musculoskeletal conditions in NZ (Reid & Larmer, 2007).

ACC policies and processes also likely contribute to the low dosage of physiotherapy treatment received by NZ ACLR patients. Based on nothing more than consensus opinion, ACC determined the maximum number of physiotherapy treatments it would fund following an ACL injury is 16. Once these treatments were used, the

physiotherapist has to apply to ACC for additional funding of further treatments. Results from chapters two and four show NZ ACLR patients receive 5-7 physiotherapy treatments prior to ACLR and less than 12 treatments following surgery. These treatment numbers suggest rehabilitation ceases for a significant number of NZ ACLR patients when they have received their allocation of 16 ACC-funded physiotherapy treatments. Therefore, the ACC physiotherapy treatment limit potentially restricts the number of physiotherapy treatments NZ ACLR patients receive. A significant number of ACLR patients report physiotherapy treatment limits, as set by an insurance provider, are a determining factor in the cessation of post-surgical physiotherapy treatment (Dunphy & Gardner, 2020). ACLR patients also report that if physiotherapy treatments are limited, they are forced to choose between using more treatments sooner to better facilitate early rehabilitation or saving treatments for use during the alter stages of rehabilitation (Paterno et al., 2019).

Once the allotted number of treatments have been used, an application for funding of additional treatment is made to ACC by the physiotherapist. Using the information within the physiotherapy clinical records, which may include generic PROMs (visual analogue scale pain scores and patient specific functional scale scores), and a completed ACC32 form, ACC's Clinical Advisor team make a recommendation if further treatments are necessary and appropriate. Therefore, a decision on whether further physiotherapy treatment is required following ACLR is based exclusively on subjective information, with no data to provide an objective representation of the patients functional status. Objective patient outcome data would provide an evidence-base for the approval or decline for funding of additional physiotherapy treatments. Physiotherapists may also be less inclined to apply for additional treatments, if the objective outcome data showed the client was making satisfactory progress and further treatments were not clinically indicated.

For physiotherapists invoicing ACC under the Allied Health Services contract, the treatment limit has recently been increased from 16 to 50 for all musculoskeletal injuries, including ACL injury. Previous research indicates 50 physiotherapy treatments would provide sufficient rehabilitation input for all but the most complex of ACL-injured patients (Dempsey et al., 2019; Walker et al., 2021; Walston & Barillas, 2021). Treatment limits for physiotherapists invoicing ACC under the Cost of Treatment

Regulations have not increased and remain at 16 for an ACL injury. There are approximately 4000 physiotherapists registered as providers with ACC, with 1800 billing ACC for treatment under the Cost of Treatment Regulations (F. Wilkins, personal communication, August 13, 2022). Therefore, 45% of private physiotherapy providers in NZ are still constrained to a limit of 16 treatments when managing an ACL injury, with those providers having to use the ACC32 process if additional treatments are required.

The results from chapter four show NZ ACLR patients receive almost 80% of their post-operative physiotherapy treatments within the first six months after surgery, which is similar to previous research showing a non-uniform temporal distribution of physiotherapy treatment after ACLR (Burroughs et al., 2021). Results from chapter five show over 50% of NZ physiotherapists would use 12 treatments within the first six weeks after ACLR. It is worth repeating here the average number of treatments NZ ACLR patients receive following surgery is less than 12. Therefore, NZ ACLR patients appear to be receiving most, if not all, of their physiotherapy treatment soon after surgery, leaving few treatments available for end-stage rehabilitation and RTS. Returning to pre-ACL injury activities is a complex and challenging process involving multidisciplinary team input, passing pre-defined functional performance criteria, and a graduated return to pre-injury activities (Buckthorpe, 2019; Meredith et al., 2020). Due to the knowledge and skills required to provide end-stage ACLR rehabilitation at an appropriate level and intensity, a higher level of supervision may be needed in the later phases to meet RTS criteria and reduce the risk of reinjury (Walker et al., 2020). If the allocated number of treatments are utilised before an ACLR patient has achieved their post-operative goals, the physiotherapist will have to apply to ACC for funding of additional treatments, which has the potential to limit the number of treatments provided.

The overall dosage of physiotherapy treatment is a product of the duration of each treatment, the number of treatments, and the time those treatments are delivered over (Snodgrass et al., 2014). Results from chapters two and four reported a low dosage of physiotherapy treatment following ACL injury and ACLR, based on the number of physiotherapy treatments, and the number of days between the first and last treatment only. No data was available for the duration of each individual

treatment, as it was not practicable to collect this information. Private practice physiotherapy treatments in NZ can range from 15-60 minutes between providers and practices. Therefore, a patient receiving 10 x 60 minute treatments would receive a greater overall dosage of treatment (600 minutes) than a person receiving 20 x 20 minute treatments (400 minutes), despite receiving half as many treatments. Therefore, results from chapters two and four regarding the overall dosage of physiotherapy treatment may not have been the most accurate representation of the exact dosage of treatment received.

End-stage ACLR rehabilitation and RTS should be managed by a rehabilitation professional experienced in ACL injuries and ACLR rehabilitation (Buckthorpe et al., 2019; Filbay & Grindem, 2019). Results from chapter five show only 3.5% of NZ physiotherapists consider ACLR patients their primary area of expertise and over half of NZ physiotherapists see five or less ACLR patients per year. Over 55% of Australian therapists see 6-20 ACLR patients per year (Ebert et al., 2019), while 38% of US physiotherapists see more than 10 ACLR patients per year (Greenberg et al., 2018), which suggests NZ physiotherapists have a lower exposure to ACLR patients than their international counterparts. A lower exposure to ACLR patients will result in NZ physiotherapists having less experience in managing the condition. Less experienced physiotherapists provide a shorter duration of treatment to ACLR patients (Greenberg et al., 2018) and may be at risk of prematurely discharging patients (Walker et al., 2020), which will ultimately influence the overall dosage of treatment received. The self-confidence of physiotherapists to deliver ACLR rehabilitation decreases over time and is lowest at 6 months post-ACLR (Dingenen et al., 2021), and ACLR patients report frustration and dissatisfaction with a physiotherapists ability to deliver and manage end-stage rehabilitation (Walker et al., 2022). Physiotherapists also report a lack of appropriate resources to deliver evidence-based ACLR rehabilitation (Dunphy & Gardner, 2020), and the lack of adequate facilities contributes to a negative patient experience during ACLR rehabilitation (Welling et al., 2022). Therefore, if a physiotherapist has a low exposure to ACLR patients, and lacks the confidence and resources to competently manage an ACLR rehabilitation programme to a satisfactory conclusion, this could result in ACLR patients seeking post-operative rehabilitation guidance from a non-physiotherapy provider (Ebert et al., 2019) and reduce their

overall dosage of physiotherapy treatment. Although the exposure of NZ physiotherapists to ACLR patients is known, this may not accurately reflect a physiotherapists experience and confidence in managing ACLR patients. A physiotherapist may have considerable previous experience with ACLR patients, with extensive knowledge of the condition, but other external factors may limit their yearly exposure to ACLR patients.

Patients describe ACLR rehabilitation as time-consuming, boring, and arduous (Piussi et al., 2022; Thorstensson et al., 2009). Patient motivation to continue with ACLR rehabilitation needs to be created and maintained (Risberg et al., 2016). Regular assessment of patient status, knee strength, and functional ability can help develop and maintain patient motivation and compliance with ACLR rehabilitation (Grindem, Risberg, et al., 2015). Over three quarters of ACLR patients consider regular assessment of their progress and function as essential or important to facilitating their rehabilitation (Walker et al., 2021). ACLR patients also report the achievement of objective milestones increases perseverance with rehabilitation (Paterno et al., 2019). However, chapter five results suggest NZ physiotherapists do not routinely assess patient status during ACLR rehabilitation. A significant percentage of ACLR patients report ceasing rehabilitation of their own volition (Dunphy & Gardner, 2020), and it is possible a lack of motivation to continue with rehabilitation contributes to this. Therefore, the lack of regular outcomes assessment of ACLR patients by NZ physiotherapists may fail to maintain patient motivation, resulting in the patient prematurely ceasing rehabilitation and receiving a low dosage of physiotherapy treatment.

The absence of objective outcome data also provides the physiotherapist with no basis to contradict the patients subjective reporting of function. If the patient reports a certain level of function, and the physiotherapist is not able to refute that report with objective data, then the physiotherapist is unlikely to convince the patient further rehabilitation is required. Previous research has shown weak correlations between subjective reports of function and physical performance in the first two years following ACLR (Bodkin et al., 2017; Reinke et al., 2011). As such, ACLR patients may over-estimate their functional ability, leading to a premature cessation of rehabilitation and physiotherapy treatment, and the false belief they are ready to return to pre-injury

activities. ACLR patients who do not complete the recommended dosage of rehabilitation following surgery are less likely to achieve the functional parameters considered necessary for a return to sport (Ebert et al., 2018), are less likely to return to sport (Edwards et al., 2018), and have a significantly higher risk of subsequent ACL injury once they have returned to sport (Beischer et al., 2020; Grindem et al., 2016; Kyritsis et al., 2016).

Contextual factors, which can be defined as physical, psychological and social elements that characterize the therapeutic encounter with the patient (Rossettini et al., 2018), can also influence patient engagement with, and utilisation of, physiotherapy treatment. Contextual factors can be related to the both the physiotherapist and patient, and the environment the treatment is delivered in (Rossettini et al., 2020). Physiotherapist-specific contextual factors include the providers experience and qualifications; patient-specific factors include ethnicity, socio-economic status, expectations regarding outcome; and the environmental contextual factors can include the clinic location (rural vs urban), clinic facilities, and patient surcharges (Testa & Rossettini, 2016).

Specific to the NZ context, patient ethnicity, specifically Māori and Pacific Island (PI), has a potentially significant influence on engagement in physiotherapy treatment, and therefore outcomes from musculoskeletal injury, such as ACLR. While 17% and 8% of NZ's general population identify as Māori and PI respectively (Statistics New Zealand, 2020), only 6% of NZ physiotherapists identify as Māori and only 1% identify as PI (Physiotherapy New Zealand, 2023). This ethnic discrepancy may result in Māori and PI being less likely to engage in physiotherapy services due to being unable to access a physiotherapist of a similar cultural background. Māori and PI in NZ are also over-represented in the poorest demographic areas and have a lower access to primary healthcare due to socio-economic status (Goodyear-Smith & Ashton, 2019; Jatrana & Crampton, 2009). Therefore, patient surcharges for private practice physiotherapy treatment in NZ likely have a significant influence on Māori and PI engagement with physiotherapy, as these ethnicities are over-represented in lower socio-economic groups (Loring et al., 2022).

In NZ, how easily a patient can access a physiotherapist may influence the overall utilisation of physiotherapy services. In urban areas, a patient may have multiple providers to choose from, with minimal travel burden and time away from work to access treatment. However, if the patient lives in rural or remote location, significant travel time and time away from work, may influence how frequently the patient chooses to access physiotherapy treatment. Only, 16% of NZ physiotherapists report working in a rural location (Physiotherapy New Zealand, 2023), which provides a limited pool of physiotherapists for patients living in rural areas to choose from. If the only physiotherapy provider accessible to the rural patient also levies a treatment surcharge that imparts a significant financial burden on the patient, this would likely exacerbate the problem and further dissuade the patient from engaging in physiotherapy.

6.4 Patient-Reported Outcomes Following Anterior Cruciate Ligament Reconstruction in New Zealand

The results from chapter four show the percentage of NZ ACLR patients achieving a KOOS^4 PASS score increases following surgery, with 75% of patients achieving an acceptable symptom state at two years. Physiotherapy treatment between 0-6 and 7-12 months after surgery increased the likelihood of achieving a KOOS^4 PASS score at 6- and 12-months respectively, but physiotherapy treatment between 13-24 months did not increase the likelihood of a PASS score at 24 months. The percentage of patients achieving a normative MARS score also increased following ACLR; however, only 28% of patients achieved this outcome by two years. Physiotherapy treatment in the 24 months following ACLR did not increase the likelihood of achieving a normative MARS within that time. A greater number of physiotherapy treatments did not increase the likelihood of achieving a KOOS^4 PASS score or normative MARS score in the 24 months following ACLR.

Physiotherapists in NZ are not required to use body-site or injury specific PROMs in their everyday clinical practice, with chapter five results confirming a low utilisation of PROMs in the management of ACLR. Therefore, to determine the relationship between physiotherapy and treatment and patient outcomes following ACLR in NZ, the outcome data from the NZ ACL Registry was selected. As such, there was no control

over the outcome measures used in the chapter four study. The NZ ACL Registry outcome data was not collected by the physiotherapists over-seeing the rehabilitation programme and the outcome measures are independent of the rehabilitation being provided. As the outcome data was not directly linked to the rehabilitation programme or patients functional status in any way, the NZ ACL Registry outcome measures may have not captured an accurate representation of the clients status at that time.

The KOOS and MARS may not be the most appropriate PROMs to assess short-term outcomes following ACLR. Recent research has suggested the KOOS lacks adequate content validity to appropriately assess patients with an ACL injury (Hansen et al., 2022). The KOOS was developed as an extension of the Western Ontario and McMaster Universities Osteoarthritis Index questionnaire, with content validity of the KOOS established on 75 patients with radiological signs of knee osteoarthritis due to meniscal injury surgery 20 years previous (Roos et al., 1998). Therefore, the KOOS lacks content likely to be important to an ACL-injured person, including the presence of instability or weakness, and difficulty with ACL-dependent activities such as stopping and starting at speed, landing from a jump, and changing direction quickly (Zsidai et al., 2022).

The MARS was developed to assess the frequency of participation in knee-strenuous activities (Marx et al., 2001). However, the population in which the MARS was validated was asked to record their highest level of participation within the last 12 months. As such, a person performing frequent knee-strenuous activities may score high on the MARS at six months post-ACLR if they underwent ACLR within six months of their ACL injury, as their 6-month post-operative MARS score would reflect their pre-injury status, not their post-injury status. Also, using the MARS to assess patient outcomes within six months of an ACLR may be inappropriate, as ACLR patients would not be expected to engage in the activities included in the MARS within six months of surgery (Meuffels et al., 2012).

MARS scores following ACLR will also be affected by the patients post-operative goals and choices regarding activity participation. A person who participates frequently in high-ACL demand activities prior to ACL injury will score highly on the MARS. If

following ACLR that person modifies their activities and chooses not to engage in ACL-dependent activities, their post-operative MARS score will be significantly lower, which would be interpreted as a poor outcome. However, the patient may in fact have had an excellent outcome from surgery – they have just elected not to engage in the ACL-dependent activities included in the MARS.

Patient-reported outcomes capture the patient's opinion regarding the impact of a condition on their life, and the effect of treatment during an episode of care (Kyte et al., 2015). During ACLR rehabilitation, PROMs are recommended for use as part of an overall suite of outcome measures to assess patient progress (Andrade et al., 2019). Although they are aware of the benefits of utilising PROMs, everyday use of them by physiotherapists in clinical practice is low, with time for patients to complete them and the time for providers to analyse them cited as major barriers to their use (Jette et al., 2009). Other barriers to using PROMs in everyday physiotherapy practice include a lack of knowledge regarding which PROM to use and how to use them, a lack of organisational support, a lack of funding to incorporate PROMs into treatment, and a patient's inability to independently comprehend and complete a PROM (Duncan & Murray, 2012). In NZ, the duration of a private physiotherapy treatment varies across providers but can be as brief as 15-20 minutes. Therefore, the duration of a physiotherapy treatment may influence PROM use by NZ physiotherapists. The duration of a private physiotherapy treatment in NZ is at the discretion of the provider; however, the various models used by ACC to fund private physiotherapy treatment in NZ may have a significant impact on the providers decision regarding the length of a treatment.

The results from chapter four showed physiotherapy treatment increased the likelihood of achieving a KOOS[4] PASS score over no physiotherapy treatment in the first year following ACLR, but more treatments did not significantly increase the likelihood of achieving a better outcome. As a greater quantity of treatment does not necessarily equal a better outcome, it may be that patient engagement with physiotherapy, motivation to achieve post-operative goals, and adherence to rehabilitation are important factors that ultimately determine how many treatments an ACLR patient will require. Once an ACLR patient has engaged with physiotherapy after surgery, the onus then falls to the provider to keep the patient sufficiently

motivated to continue with rehabilitation for as long as necessary to achieve their goals (Grindem, Risberg, et al., 2015). Self-motivation is positively associated with adherence to ACLR rehabilitation (Brewer et al., 2000; Mendonza et al., 2007), and patient motivation during ACLR rehabilitation is created and maintained by regular assessment of patient status and functional ability (Risberg et al., 2016). However, as per chapter five, a low percentage NZ physiotherapists report utilising valid and reliable methods to assess patient status and function during ACLR rehabilitation, which could negatively impact patient motivation, therefore reducing patient engagement and overall utilisation of physiotherapy treatment.

6.5 Implications for Physiotherapy Practice Following Anterior Cruciate Ligament Reconstruction in New Zealand

Treatment decisions by ACC and health providers following ACL injury are often made in isolation, resulting in a disconnected management process (von Aesch et al., 2016). Good communication between the orthopaedic surgeon and physiotherapist, working within a multidisciplinary team (MDT) (van Melick et al., 2016), enhances and optimises the patients post-operative rehabilitation experience (Filbay & Grindem, 2019; Paterno et al., 2019). Therefore, it may be beneficial for NZ physiotherapists to develop and maintain communication pathways with the orthopaedic surgeons who perform ACLR surgeries on their patients, as this may improve patient experience and outcome during post-ACLR rehabilitation.

NZ physiotherapists should increase their skills and knowledge regarding end-stage ACLR rehabilitation, which may require attendance at courses or undertaking post-graduate education. Mentoring from another physiotherapist with greater experience in overseeing RTS following ACLR may also increase provider knowledge in this area (Jensen et al., 2000). NZ physiotherapists could also develop connections with strength and conditioning coaches or exercise physiologists, as these providers likely possess the skills and resources to competently oversee the functional component of end-stage ACLR rehabilitation. Strength and conditioning coaches in NZ report minimal input during injury rehabilitation, which can be due to a lack of communication and collaboration between providers (Armstrong et al., 2021). Therefore, a strength and conditioning coach/physiologist should be included in any

early MDT discussions regarding treatment decisions following ACL injury. Aligning with a sports team/club/organisation will enhance the relationship with the strength and conditioning coach associated with that sport, while also increasing the physiotherapists knowledge of the sport involved, which may increase the ability of the physiotherapist to oversee the patient's return to that specific sport following ACLR (Buckthorpe, 2019).

A significant finding of this thesis was the absence of outcome measures collected by NZ physiotherapists during ACLR rehabilitation and the potential impacts of that. Therefore, it is recommended NZ physiotherapists utilise appropriate PROMs at regular intervals throughout the ACLR rehabilitation process. The International Knee Documentation Committee (IKDC) form includes items considered more important to ACLR patients than the KOOS (Hambly & Griva, 2010), and as such, is a more useful tool to evaluate patients in the first year after surgery (van Meer et al., 2013). The Tegner Activity scale (TAS) has received superior psychometric scrutiny than the MARS (Letchford et al., 2012), and its use is recommended when assessing activity levels in ACLR patients, particularly in conjunction with the IKDC (Wera et al., 2014).

NZ physiotherapists should also utilise valid and reliable methods to assess patient strength and functional ability during ACLR rehabilitation. The collection of such data requires the physiotherapist to have access to valid and reliable methods to assess such variables. The majority of NZ physiotherapists do not use objective methods to directly assess lower limb strength, with only a small percentage using hand-held dynamometry (HDD) and very few having access to isokinetic dynamometry, which is the recommended 'gold-standard' method to assess knee flexor and extensor strength following ACLR (Nagai et al., 2020; Petersen et al., 2014). Therefore, to ensure accurate assessment of knee strength, NZ physiotherapists should consider using HDD to assess knee strength, with additional efforts made to remove the barriers limiting access to isokinetic testing facilities. As there is poor agreement between HDD and isokinetic dynamometry when evaluating lower limb strength following ACLR, the instruments should not be used interchangeably (Ivarsson & Cronström, 2022).

The majority of NZ physiotherapists use hop tests to assess the functional performance of ACLR patients, as these require little resource and are easily performed in a clinic

setting. A battery of hop tests is recommended to assess lower limb function following ACLR (Ebert et al., 2021); however, as their relationship with knee strength is less convincing, they should not be used to estimate knee strength. Quality of movement during hop tests should also be assessed, as using hop distance as the sole determinant of performance can over-estimate recovery (Davies et al., 2020).

The routine collection of objective patient outcome data during ACLR rehabilitation will likely have several benefits. Patient progress can be monitored by regular assessment, with the rehabilitation plan quickly modified or adjusted based on the results. Regular assessment will enhance a patient's motivation to continue with, and complete, a comprehensive rehabilitation programme, which will increase the likelihood of achieving better short- and long-term outcomes. Outcome data can provide a clear, objective rationale that supports the need for additional treatments should they be required, while also establishing the value of physiotherapy treatment to third party funders. Collated outcome data could then be used to benchmark a typical outcome following ACLR. Such data could then be used in two ways: (i) to identify patients who may not be progressing as expected, and (ii) to identify providers whose patients may not be achieving similar outcomes to the patients of other providers.

Telehealth, including telephones, smartphones, and mobile wireless devices with a video connection, is increasingly being used in healthcare as a means of service provision (Dorsey & Topol, 2016). Due to access barriers, telehealth in musculoskeletal physiotherapy and rehabilitation can offer a viable alternative to in-person care (Cottrell & Russell, 2020). The majority of ACLR patients consider telerehabilitation is an acceptable substitute for face-to-face treatment, with the proviso the technology is of an appropriate standard to allow an acceptable level of service to be delivered (Dunphy & Gardner, 2020). ACLR patients report telerehabilitation can reduce financial and travel burdens associated with ACLR rehabilitation, but only in conjunction with in-person appointments, as patients still perceive periodic face-to face treatment as important to their recovery (Dunphy & Gardner, 2020; Walker et al., 2022). Therefore, telerehabilitation could be a practical solution to remove access barriers for ACLR patients in NZ who live rurally and are unable to easily access physiotherapy services. In-person treatments should be interspersed with

telerehabilitation sessions, as these are valued by the patient and allow for instant feedback to be provided on exercise intensity and technique (Dunphy & Gardner, 2020).

6.6 Strengths and Limitations of this Thesis

6.6.1 Strengths

The physiotherapy treatment data utilised in chapters two and four was extracted directly from the ACC database, which is an electronic system based on invoicing records ensuring the accuracy of the data, while also providing a 'real world' view of the physiotherapy treatment received following ACLR in NZ. The strengths of the systematic review in chapter three include the search strategy assistance of a senior faculty librarian, prospective registration, and the quality appraisal of the selected studies using a validated assessment tool. The large participant population in the chapter four study allowed for a robust statistical analysis to be performed, despite the exclusion of subjects with incomplete outcome data. As part of the survey in chapter five, physiotherapists who were considered more likely to be involved in treating ACLR patients were specifically approached to participate in the study, which increases the validity of participant responses.

6.6.2 Limitations

The absence of patient outcome data from chapter two prevents any conclusions being made regarding the effectiveness of the physiotherapy received or any comparisons being made between the three groups of subjects. The findings of the systematic review in chapter three are based on data from studies that did not specifically align with the specific question of the review. Limitations from chapter four include the retrospective study design, the absence of participant contextual data e.g. location, ethnicity etc, the potential for participants to have multiple claims related to a single ACL injury, and the lack of control over which PROM data was collected. Regarding chapter five, a relatively low response rate, targeting of specific participant groups, variability in interpreting the survey items by participants, and the absence of participant demographic and contextual data can be identified as potential limitations.

6.7 Future Research Opportunities

The findings of this thesis have led to several possible areas for future research. We highlighted discrepancies between the dosage of treatment NZ physiotherapists believe is required following ACLR and the actual dosage of physiotherapy treatment NZ ACLR patients receive following surgery. Therefore, a qualitative study of NZ physiotherapists into the barriers and facilitators that contribute to ACLR patients receiving a dosage of treatment that differs to what physiotherapists believe is required after surgery may offer additional insights and identify opportunities to improve service delivery. Such a study could also explore the barriers and facilitators to the routine utilisation of PROMs in clinical practice by NZ physiotherapists, particularly in the context of an ACLR. A similar qualitative study of NZ ACLR patients could be undertaken to explore the patient experience of ACLR rehabilitation in NZ and the barriers/facilitators to physiotherapy treatment following surgery. A further qualitative study of NZ Orthopaedic surgeons regarding their opinions and beliefs on pre- and post-ACLR physiotherapy treatment and rehabilitation would offer further insights into the barriers patients may encounter to accessing physiotherapy treatment.

Given the recent increase in treatment limits for contracted physiotherapists, a repeat of the descriptive analysis from chapter two is recommended to determine if the change in physiotherapy treatment limits has resulted in patients receiving an increased dosage of physiotherapy treatment following ACLR in NZ. Particular focus should be given to the dosages of treatment provided by contracted and non-contracted physiotherapists.

The findings and recommendations of this thesis are based on physiotherapy treatment data and patient outcome data collected prior to 2020. It must be noted that since 2020, ACC has commenced two significant pieces of work, which are intimately related to the findings of this thesis. The first piece of work is known as the Escalated Care Pathway (ECP), which involves a coordinated, interdisciplinary team approach to complex musculoskeletal injuries in the shoulder, lumbar spine, and knee (including ACL injuries). Once a patient has entered the ECP, management of their injury is overseen by a team of health professionals, which includes a physiotherapist,

Orthopaedic surgeon, psychologist, and vocational consultant. The ECP differs from regular care in several distinct areas. During the ECP, outcome data is collected by the rehabilitation provider at regular intervals throughout the course of treatment, which allows for real-time monitoring of patient progress and adjustment of the treatment plan if required. There are no time limits or treatment limits on service delivery, with the patient receiving the amount of treatment necessary to achieve whatever goals have been set upon their entry into the programme. All treatment is fully funded by ACC, with no co-payments levied against the patient, which removes a significant financial barrier to the patient receiving a sufficient dosage of treatment. The second piece of work ACC is currently engaged in is a pilot study, in collaboration with Physiotherapy New Zealand, to test the viability of collecting PROM data from ACC-funded patients receiving physiotherapy treatment. Outcome data will be collected at pre-defined time points during treatment, with the aim to help ACC better understand (i) client outcomes following injury and (ii) the effectiveness of physiotherapy treatment provided during recovery from injury.

With the introduction of the ECP, it would be prudent to undertake an analysis to compare the outcomes of ACLR patients managed via the ECP verses usual care, again with an emphasis on the dosage of physiotherapy treatment received by patients under each pathway. Collecting demographic and contextual data for both physiotherapy providers (e.g. qualifications, years of experience, location) and patients (e.g. ethnicity, socio-economic status) would enable further insights into how these factors may also influence physiotherapy utilisation. Additionally, a well-controlled study examining the effects of different dosages of physiotherapy treatment on outcomes following ACLR could be performed; however, the ethical constraints around restricting the amount of physiotherapy treatment a patient can receive would likely render the undertaking of such a study unfeasible.

6.8 Summary and Conclusions

The primary purpose of this thesis was to investigate the relationship between physiotherapy treatment and patient outcomes following ACLR in NZ. The importance of this research is highlighted by (i) the amount of physiotherapy treatment NZ ACLR patients receive following surgery was unknown, (ii) the beliefs and opinions of NZ

physiotherapists regarding ACLR rehabilitation was unknown, (iii) the lack of high-quality research specifically examining the relationship between physiotherapy treatment and patient-reported outcomes following ACLR.

The major findings of this thesis were (i) NZ ACLR patients receive a low dosage of physiotherapy treatment following ACLR, (ii) the beliefs of NZ physiotherapists regarding treatment following ACLR are incongruent with the dosage of treatment patients are actually receiving, (iii) the dosage of post-ACLR physiotherapy treatment does not appear to have a significant effect on patient outcomes, (iv) physiotherapy treatment in the 12 months following ACLR may increase the patients acceptance of any ongoing knee symptoms or functional limitations.

There is no evidence from this thesis that the dosage of physiotherapy treatment received following ACLR has a significant effect on post-operative outcomes, and the optimal dosage of physiotherapy treatment following ACLR remains unknown. Just as the management of an ACL injury is highly individualised, it is likely the dosage of post-operative physiotherapy treatment will also vary considerably between patients – a reflection of the individuals' goals and progress during rehabilitation. The number of physiotherapy treatments required following an ACLR will ultimately be the number of treatments a patient needs to achieve their post-operative goals.

While multiple factors influence a dosage of physiotherapy treatment, it is likely ACC policies and processes have contributed to the low dosage of post-ACLR physiotherapy treatment. It bodes well for future ACLR patients in NZ that the primary funder of ACLR rehabilitation has recently recognised a pre-determined number of physiotherapy treatment following ACLR may not be the most appropriate method to fund post-operative rehabilitation, with the value of physiotherapy treatment better measured by objective patient outcomes than the dosage of treatment a patient receives.

This thesis has also highlighted the potentially significant impacts of NZ physiotherapists not regularly collecting outcome data or assessing patient function following ACLR on the dosage of post-operative treatment received. Several opportunities exist for physiotherapy practice in NZ to improve its contribution to the management of ACLR rehabilitation, with routine collection of patient outcomes,

improving communication with other providers within an MDT context, and upskilling in end-stage ACLR rehabilitation.

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Appendices

Appendix A.
Physiotherapy treatment and rehabilitation following anterior cruciate ligament injury in New Zealand: Are we doing enough? Published in New Zealand Journal of Physiotherapy.

RESEARCH REPORT

Physiotherapy treatment and rehabilitation following anterior cruciate ligament injury in New Zealand: Are we doing enough?

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ABSTRACT

Physiotherapists are lead providers of rehabilitation following anterior cruciate ligament injury in New Zealand. Rehabilitation is considered an essential component following anterior cruciate ligament injuries, but there is considerable variability regarding pre- and post-operative management. This study used data from the Accident Compensation Corporation (ACC) for the years 2013/14 to 2015/16 to gain insight into the physiotherapy management of anterior cruciate ligament injuries in New Zealand. Data were extracted from 647 claims from people with a completed anterior cruciate ligament reconstruction and 221 claims from people with a confirmed injury who did not undergo surgery. In the 12 months following either anterior cruciate ligament injury or surgery, 81% of claimants had fewer than 15 ACC-funded physiotherapy treatments, and 13% of claimants had no ACC-funded physiotherapy treatments. Nine percent of claimants had a previous or subsequent claim for an anterior cruciate ligament injury. Compared to best practice literature, the results indicate a significant number of people in New Zealand received fewer than the recommended number of physiotherapy treatments following anterior cruciate ligament injury. Possible reasons may include the cost of private physiotherapy services, a lack of endorsement from the respective orthopaedic surgeons, decreased patient adherence/motivation and decreased patient understanding of the importance of rehabilitation.

Fausett, W., Wilkins, F., Reid, D., Larmer, P., & Potts, G. (2019). Physiotherapy treatment and rehabilitation following anterior cruciate ligament injury in New Zealand: Are we doing enough? *New Zealand Journal of Physiotherapy, 47*(3), 139-149. https://doi.org/10.15619/NZJP/47.3.02

Key Words: Anterior Cruciate Ligament, Physiotherapy, Treatment, Rehabilitation

INTRODUCTION

Injury to the anterior cruciate ligament (ACL) of the knee is a common occurrence in an active population (Gianotti, Marshall, Hume, & Bunt, 2009; Majewski, Susanne, & Klaus, 2006). Following ACL injury, the two traditional management pathways are: 1) early ACL reconstruction (ACLR) surgery followed by rehabilitation; and 2) conservative management consisting of rehabilitation, with the option of delayed ACLR if required (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005; Risberg, Lewek, & Snyder-Mackler, 2004; Zadro & Pappas, 2018). The exact incidence of ACL injury is not known as not all ACL injuries are diagnosed or proceed to surgery (Janssen, Orchard, Driscoll, & Van Mechelen, 2012). ACL surgical rates are often used as surrogate estimates of injury rates (Moses, Orchard, & Orchard, 2012; Sanders, Maradit Kremers, Bryan, Larson, et al., 2016), with rates of ACLR increasing worldwide (Abram, Price, Judge, & Beard, 2019; Sanders, Maradit Kremers, Bryan, Larson, et al., 2016; Zbrojkiewicz, Vertullo, & Grayson, 2018). An increasing ACLR rate is associated with increased work absenteeism, rehabilitation costs and an increased rate of degenerative knee conditions and knee joint arthroplasty (Barenius et al., 2014; Cinque, Dornan, Chahla, Moatshe, & LaPrade, 2017; Janssen et al., 2012; Khan et al., 2018; Suter et al., 2017).

The Accident Compensation Corporation (ACC) of New Zealand provides 24-hour comprehensive no-fault accident insurance to compensate the injured person and assist them in returning to independence by covering medical costs, other entitlements and ensuring timely access to treatment (Flood, 2000). Annually, ACC spends over $25 million on ACL surgeries and over $100 million on physiotherapy services for all injuries (ACC, 2018a). Entitlements and the cost of physiotherapy treatment will vary depending on the injured person's work status or capacity and the contracts held by the treating physiotherapist. ACC purchases physiotherapy treatment in three ways: either via the cost of treatment regulations or the physiotherapy services contract (ACC, 2018b) or vocational rehabilitation services (VRS). The ACC contribution may not fully cover the cost of treatment and some private physiotherapy practices charge a co-payment

of up to $50 per treatment (Fitzjohn, 2007). Claimants who are unable to complete work duties and receive earnings-related compensation (ERC) are entitled to VRS, which support and facilitate a return to work (ACC, 2015), are fully funded and may include physiotherapist-led functional rehabilitation (ACC, 2018c).

Rehabilitation following ACL injury or ACLR should encompass a biopsychosocial approach (Scott, Perry, & Sole, 2018), which addresses patient education, physical rehabilitation and psychological barriers (Filbay & Grindem, 2019; Risberg, Grindem, & Oiestad, 2016; Zadro & Pappas, 2018). The physical component of rehabilitation involves restoration of knee range of movement, lower limb strengthening, neuromuscular and proprioceptive retraining, and activity specific exercises (Adams, Logerstedt, Hunter-Giordano, Axe, & Snyder-Mackler, 2012; Myer, Paterno, Ford, Quatman, & Hewett, 2006). Physical rehabilitation following ACL injury is safe and efficacious (Eitzen, Moksnes, Snyder-Mackler, & Risberg, 2010), with the ultimate goal of rehabilitation to achieve a sustainable return to pre-injury activities (Risberg et al., 2004). Physiotherapists with expertise in the function of the musculoskeletal system have the knowledge and skills to implement and progress the physical and functional components of ACL rehabilitation (van Melick et al., 2016).

A structured pre-operative physical rehabilitation programme produces better post-operative functional outcomes (Eitzen, Risberg, & Holm, 2009; Failla et al., 2016; Logerstedt, Lynch, Axe, & Snyder-Mackler, 2013). Supervised physiotherapy is routinely prescribed following ACL surgery (Han, Banerjee, Shen, & Krishna, 2015), and supervised rehabilitation can be associated with better outcomes than unsupervised (Christensen, Miller, Burns, & West, 2017). Physical rehabilitation lasting up to 12 months is recommended after ACLR to restore function and stability to the knee (Adams et al., 2012; Zadro & Pappas, 2018), and to optimise post-surgical outcomes (Grindem, Granan, et al., 2015). Recent evidence suggests people may not be completing sufficient post-ACLR rehabilitation before returning to pre-injury activities (Ebert, Edwards, et al., 2018; Grindem, Arundale, & Ardern, 2018). Irrespective of how an ACL injury is managed, a significant percentage of people do not return to pre-injury activity levels (Ardern, Taylor, Feller, & Webster, 2014; Øiestad, Holm, & Risberg, 2018; Webster & Feller, 2018), or they suffer a subsequent ACL injury (Crawford, Waterman, & Lubowitz, 2013; Lai, Ardern, Feller, & Webster, 2017; Wright, Magnussen, Dunn, & Spindler, 2011).

The content and quality of ACL rehabilitation protocols is highly variable (Ajuied et al., 2014), which may lead to confusion among patients and physiotherapists (Makhni et al., 2016). Patient outcomes following ACL rehabilitation could also be influenced by patient individuality and variability in the implementation of specific ACL rehabilitation protocols by physiotherapists (Adams et al., 2012; Greenberg, Greenberg, Albaugh, Storey, & Ganley, 2018; Myer et al., 2006).

The aim of this study was to undertake a retrospective review of a three-year period of ACC claim data to gain insight into the management of ACL injury in New Zealand, with a particular focus on the quantity and duration of physiotherapy treatment following injury, and during the pre- and post-operative rehabilitation periods.

METHODS

Ethical approval was sought retrospectively. However, as advised by the Auckland University of Technology Ethics Committee, this study did not meet the threshold to require ethical approval as all data remained de-identified during collection and analysis. Use of ACC claim data complied with standard ACC consent and legal obligations related to ACC cover.

A descriptive methodology was undertaken for the study. The study cohort included all claims with an approved ACLR request for the years 2013/14, 2014/15 and 2015/16 (the year being 1 July to 31 June). Claims with an approved ACLR request were assumed to have a confirmed diagnosis of an ACL rupture. ACC claim numbers were used to identify claims. Claims were categorised as either surgical for those who had undergone surgery (Surgery Group) or non-surgical (Non-Surgery Group), and were stratified by gender and age at the date of injury (DOI) (<20, 20-29, 30-39, 40-49, 50+ years of age). Using a random number generator in Microsoft Excel, a sample of 20 claims was selected from each year according to age and gender. Where there were fewer than 20 claims for an age and gender group for that year, all claims were included in the sample. Convenience sampling was used to ensure the total sample included a similar number of males and females, and that all age ranges were equally represented. In addition, all claims where individuals had undergone ACL surgery more than 365 days after DOI were categorised as "delayed surgery" (Delayed Surgery Group), and data from this group were analysed separately.

For the Surgery Group and Non-Surgery Group, data collected via ACC's internal database and payments system included:

- mechanism of injury
- activity being performed when ACL injury occurred
- date of last physiotherapy treatment
- total earnings-related compensation (ERC) days paid under that claim
- whether there was an approved purchase order for vocational rehabilitation in the 12 months following surgery or injury
- whether the client had suffered a previous or subsequent ACL injury.

Additional data collected for the Surgery Group included the date of surgery, number of pre-ACLR physiotherapy treatments and number of post-ACLR physiotherapy treatments within 12 months of surgery. Additional data collected for the Non-Surgery Group included the total number of physiotherapy treatments within 12 months of injury. The 12-month period was chosen as this is the recommended duration of rehabilitation following ACL injury (van Melick et al., 2016).

RESULTS

The selection of claims for analysis is described in Figure 1. From the Surgery Group, two claims were excluded as the clients had not undergone ACLR, and one claim was excluded as the ACL was found intact at the time of surgery. From the Non-Surgery Group, six claims were excluded as the ACL was subsequently revealed to be intact, and seven claims were excluded as the clients had undergone ACLR within 12 months of injury. Overall, the Surgery Group, Delayed Surgery Group, and Non-Surgery Group represented 8%, 2.5%, and 3.5% respectively of the total population.

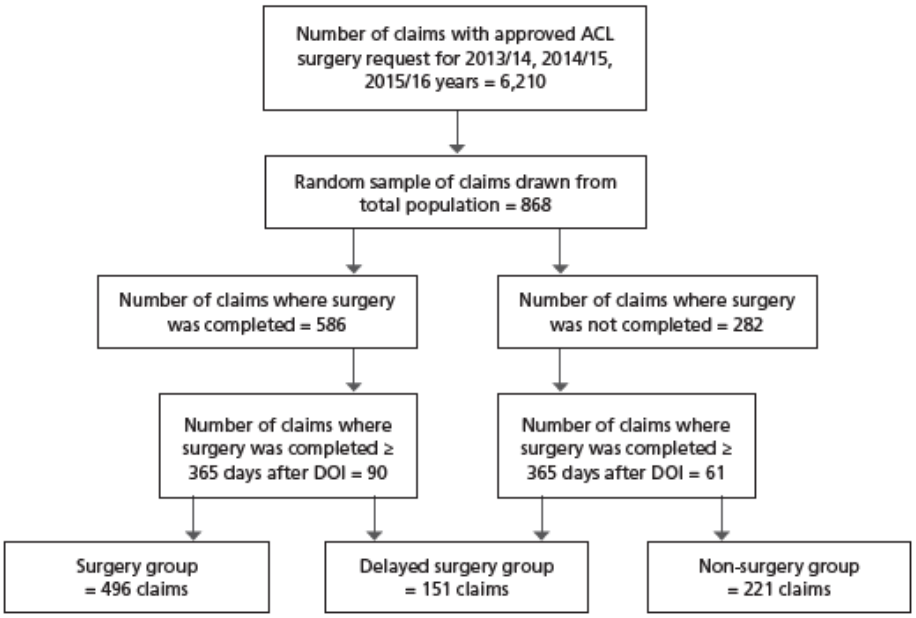

Figure 1: Flow diagram describing sample selection and how each study group was determined

Note: ACL, anterior cruciate ligament; DOI, date of injury

Across the three groups, average age at DOI was 33.4 ± 13.2 years (range 9-74 years). The percentage of male subjects was 48%, 62% and 58% respectively. The most common activity being performed when suffering an ACL injury was sports followed by recreational activities (Figure 2). Netball was the most common sport being played when suffering an ACL injury, followed by rugby, soccer and touch rugby (Figure 3). Notably, 74% (642/868) of ACL injuries involved a non-contact mechanism of injury.

Duration and quantity of physiotherapy treatment

For the Surgery Group (n = 496), 120 claims (24.2%) had no pre-ACLR physiotherapy treatments. Of the 376 claims (75.8%) with pre-ACLR physiotherapy treatments, the number of treatments averaged 7 ± 5 (range 1-33) (Figure 4). In the 12 months following ACLR, 456 claims (91.9%) had post-ACLR physiotherapy treatment, with the average number of treatments being 12 ± 8 (range 1-54) (Figure 5). The average time between surgery and the last physiotherapy treatment was 161 ± 143 days.

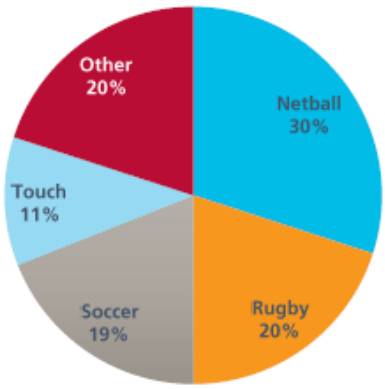

Figure 2: Activity being performed when anterior cruciate ligament injury occurred

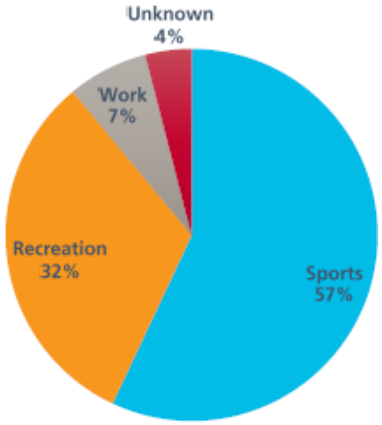

Figure 3: Sport being played when anterior cruciate ligament injury occurred

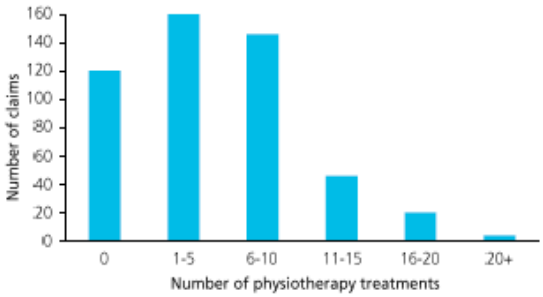

Figure 4: Number of physiotherapy treatments for the Surgery Group prior to anterior cruciate ligament surgery

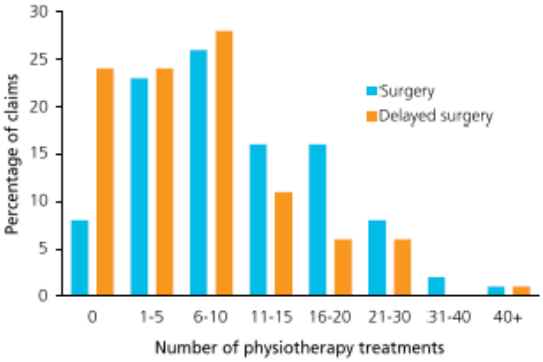

Figure 5: Number of physiotherapy treatments per claim for the Surgery Group and Delayed Surgery Group in the 12 months following anterior cruciate ligament surgery

For the Delayed Surgery Group (n = 151), 109 claims (72.1%) had physiotherapy treatment in the 12 months following DOI, with an average of 8 ± 8 (range 1-49) treatments (Figure 6). In the 12 months following ACLR, 115 claims (76.1%) had physiotherapy treatment, with the average number of treatments being 10 ± 9 (range 1-59) (Figure 5). The average time between surgery and the last physiotherapy treatment was 143 ± 95 days.

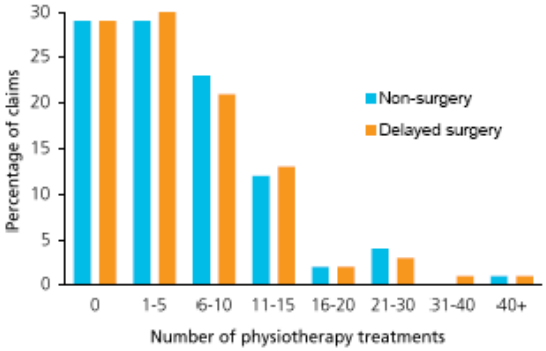

Figure 6: Number of physiotherapy treatments per claim for the Non-Surgery Group and Delayed Surgery Group in the 12 months following anterior cruciate ligament injury

For the Non-Surgery Group (n = 221), 157 claims (71.0%) had physiotherapy treatment in the 12 months following DOI, with an average of 8 ± 6 (range 1-42) treatments (Figure 6). The average time between DOI and the last physiotherapy treatment was 90 ± 84 days.

Earnings related compensation and vocational rehabilitation

For the Surgery Group, 80 claims (16.1%) had ERC paid in the two weeks prior to ACLR. Following surgery, 247 claims (49.8%) had ERC paid for an average of 102 ± 93 days (range 3-809). In the 12 months after ACLR, 129 claims (26.0%) had approved VRS, with an average duration of 149 ± 100 days (range 3-809) of ERC paid. For claims with approved VRS, the average number of physiotherapy treatments in the 12 months following ACLR was 11 ± 8 (range 1-54). Of the 40 claims (8.0%) with no post-ACLR physiotherapy treatments, nine had approved VRS, and the average number of ERC days paid on those claims was 181 ± 63.

For the Delayed Surgery Group, nine claims (6%) had ERC paid in the two weeks prior to ACLR. Following surgery, 63 claims (41.7%) received ERC for an average of 93 ± 104 days (range 11-611). In the 12 months after ACLR, 35 claims (23.1%) had approved VRS, with an average duration of 118 ± 122 days (range 27-611) ERC paid. For claims with approved VRS, the average number of physiotherapy treatments in the 12 months following ACLR was 11 ± 7 (range 2-29). Of the 36 claims (23.8%) with no post-ACLR physiotherapy treatments, three had approved VRS, with an average number of ERC days paid of 84.

For the Non-Surgery Group, in the 12 months following injury, nine claims (4.0%) had approved VRS, with an average of 147 ± 98 days (range 44-317) of ERC paid. For claims with approved VRS, the average number of physiotherapy treatments in the 12 months following DOI was 9 ± 7 (range 2-23). Of the 64 claims (28.9%) with no physiotherapy treatments in the 12 months following DOI, two had approved VRS, with an average of 173 days paid ERC.

Time to surgery

For the Surgery Group, the average number of days between DOI and ACLR was 121 ± 74 (range 22-361), with 228 people (45.9%) undergoing ACLR within 90 days of injury and 397 people (80.0%) undergoing ACLR within 180 days of injury (Figure 7). For the Delayed Surgery Group, the time between DOI and ACLR was on average 908 ± 565 days (range 369-2939).

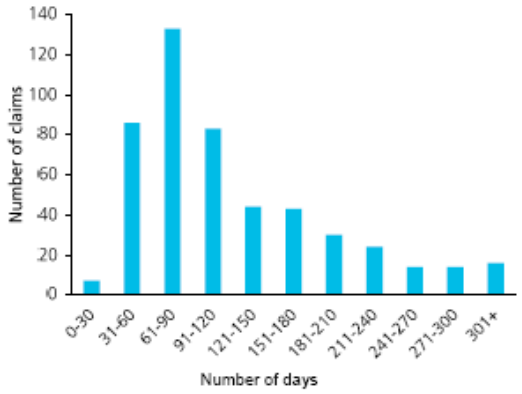

Figure 7: Number of days between anterior cruciate ligament injury and surgery for the Surgery Group

Subsequent ACL injury

For all groups (n = 868), 95 people (10.9%) had suffered multiple ACL injuries. Across the Surgery Group and Delayed Surgery Group (n = 647), 50 people (7.7%) suffered a subsequent ACL injury following ACLR, i.e. 33 (5.1%) ACL graft ruptures and 17 (2.6%) contralateral ACL injuries. The average duration between ACLR and subsequent ACL injury was 617 ± 371 days and 1,210 ± 855 days for the Surgery Group and Delayed Surgery Group, respectively. For both groups, 28 people (4.3%) had suffered a previous contralateral ACL injury and three had sustained a previous ipsilateral ACL injury.

For the Non-Surgery Group, one individual suffered a contralateral ACL injury 392 days after the initial ACL injury; 11 had suffered a previous contralateral ACL injury, eight of whom had undergone ACLR, with two sustaining subsequent ACL graft ruptures.

DISCUSSION

The aim of this study was to present a retrospective descriptive analysis of ACC claim data to gain insights into the duration and quantity of physiotherapy treatment following ACL injury in New Zealand. Our findings show that sporting and recreational activities accounted for the majority of ACL injuries, with popular change-of-direction activities in New Zealand (e.g. netball, rugby, soccer and touch rugby) responsible for the greatest number of sporting ACL injuries, which is similar to previous findings (Gianotti et al., 2009; New Zealand ACL Registry, 2018). Nearly three-quarters of all ACL injuries in the current study involved a non-contact mechanism of injury, which is consistent with previous reports of 72% prevalence (Boden, Dean, Feagin, & Garrett, 2000).

Duration and quantity of physiotherapy treatment

Our results suggest New Zealanders are not receiving physiotherapy treatment for an appropriate duration following ACL injury or surgery. Post-ACLR rehabilitation lasting up to 12 months is associated with improved knee flexor/extensor strength (Ageberg, Thomeé, Neeter, Silbernagel, & Roos, 2008; Heijne & Werner, 2007; Risberg & Holm, 2009), greater performance during functional testing (Ebert, Edwards, et al., 2018), a greater rate of returning to pre-injury activities (Ardern et al., 2014; Della Villa et al., 2012; Edwards et al., 2018; Han et al., 2015; Rosso et al., 2018) and decreased re-injury risk (Grindem, Snyder-Mackler, Moksnes, Engebretsen, & Risberg, 2016). Traditional progressions through ACL rehabilitation have been time based, which may result in sub-optimal outcomes, as time after ACLR is not necessarily related to functional performance (Myer et al., 2012). Although post-surgical rehabilitation is recommended for nine to 12 months (van Melick et al., 2016), criterion-based measures of functional performance, incorporated within a biopsychosocial framework, are also recommended to determine rehabilitation progress (Dingenen & Gokeler, 2017; Larsen, Farup, Lind, & Dalgas, 2015; Myer et al., 2006).

Our results have highlighted a potential under-utilisation of physiotherapy treatment following ACL injury and surgery, and prior to ACLR in New Zealand. Physiotherapists consider pre-operative rehabilitation to have an important influence on post-operative outcomes (Ebert, Webster, Edwards, Joss, D'Alessandro, et al., 2018). A structured physiotherapy-led pre-ACLR rehabilitation programme of up to 27 sessions has been shown to be effective and safe, and to improve outcomes two years after ACLR (Alshewaier, Yeowell, & Fatoye, 2017; Eitzen et al., 2010; Eitzen et al., 2009; Failla et al., 2016; Logerstedt et al., 2013). Our research found that 24% of people did not receive physiotherapy treatment prior to ACLR, which suggests the post-operative outcomes for almost a quarter of people in our sample may have been sub-optimal.

While many factors potentially influence outcomes after ACL injury and surgery, rehabilitation remains an important variable (Ebert, Webster, Edwards, Joss, D'Allesandro, et al., 2018) and is almost universally recommended (Adams et al., 2012; Ebert, Webster, Edwards, Joss, D'Alessandro, et al., 2018; Lobb, Tumilty, & Claydon, 2012; van Melick et al., 2016). Over 80% of Australian physiotherapists believe six to 12 treatments are required in the first six weeks after ACL surgery (Ebert, Webster, Edwards, Joss, D'Alessandro, et al., 2018), with a physiotherapist review recommended every two weeks (Filbay & Grindem, 2019). Therefore, rehabilitation lasting from nine to

12 months would equate to between 21 and 35 physiotherapy visits within 12 months following ACL surgery. It appears people in the current study received considerably less physiotherapy treatment than evidence-based guidelines suggest; the reasons for this require further evaluation.

There are multiple barriers to people engaging in a healthcare service, which includes physiotherapy following ACL injury/surgery (Carrillo et al., 2011). Patient-specific barriers include health literacy/understanding of the condition, cultural beliefs and socio-economic status; provider-specific barriers include clinician skills/knowledge and patient interactions; healthcare system barriers include cost, accessibility/waiting times, location of services and the involvement of multiple providers (Bath et al., 2016; Douthit, Kiv, Dwolatzky, & Biswas, 2015; Scheppers, Van Dongen, Dekker, Geertzen, & Dekker, 2006). In New Zealand, barriers to engaging with primary healthcare services include location, cost, suitability and awareness of services (Ministry of Health, 2001). Strategies to overcome these barriers include encouraging early, appropriate intervention within a patient's locale, ensuring cost- effective services within an accountable healthcare system and empowering people by improving health literacy through quality education (Ministry of Health, 2016).

The cost of private physiotherapy services may influence physiotherapy utilisation (Ebert, Webster, Edwards, Joss, D'Alessandro, et al., 2018). ACL rehabilitation in New Zealand is commonly supplied by private physiotherapy providers, who may charge a co-payment of up to $50 per treatment. Although physiotherapy is available via the public health system at no cost, the vast majority of people seek physiotherapy from private providers (ACC, 2018a), who make up almost 70% of New Zealand's physiotherapy workforce (Physiotherapy New Zealand, 2018). Although there are a small number of private physiotherapists in New Zealand who do not charge a co-payment, unless the person is receiving VRS from ACC, it is likely they will have to contribute to the cost of physiotherapy treatment or rehabilitation services. As such, socio-economic status could be a barrier to utilisation of physiotherapy services.

A lack of endorsement of rehabilitation by orthopaedic surgeons may have influenced physiotherapy treatment numbers in this study. Almost 40% of orthopaedic surgeons in Australia do not consider pre-ACLR rehabilitation necessary, and a small percentage even consider post-ACLR rehabilitation unnecessary (Ebert, Webster, Edwards, Joss, D'Allesandro, et al., 2018). While the surgeon is responsible for the surgery, the physiotherapist should lead the decision-making in rehabilitation (van Melick et al., 2016). Good communication between the surgeon and physiotherapist is essential following ACL injury (Grindem et al., 2018) to overcome any potential disconnect between providers (von Aesch, Perry, & Sole, 2016).

ACL rehabilitation is described by some patients as time consuming and boring, and perceived as being unable to provide sufficient results within a reasonable timeframe (Thorstensson, Lohmander, Frobell, Roos, & Gooberman-Hill, 2009); this is likely to contribute to decreased compliance with rehabilitation exercises following ACLR (Risberg et al., 2016). Poor adherence to treatment recommendations may influence physiotherapy utilisation and have a significant impact on clinical outcomes (Pizzari, McBurney, Taylor, & Feller, 2002; Vermeire, Hearnshaw, Van Royen, & Denekens, 2001). Early physiotherapeutic intervention after ACL injury, including education about the importance of rehabilitation, could positively influence the patient experience and may increase adherence to rehabilitation (Grindem, Risberg, & Eitzen, 2015; Risberg et al., 2016; Scott et al., 2018). Increased adherence to rehabilitation is positively associated with functional ability following ACLR (Brewer et al., 2000; Pizzari, Taylor, McBurney, & Feller, 2005; Rosso et al., 2018).

Patients may not be adequately informed about the rehabilitation requirements after ACL surgery (Cailliez et al., 2012). Limited understanding of the importance of rehabilitation can negatively influence patient motivation (Grindem, Risberg, et al., 2015) and patients may have high expectations regarding functional outcomes after primary ACLR (Webster & Feller, 2019). Although patient expectations align closely with the surgeons (Khair, Ghomrawi, Wilson, & Marx, 2018), the reality is these expectations are frequently not met (Ardern et al., 2014). A lack of patient education regarding the rehabilitation requirements may contribute to unrealistic patient expectations concerning the outcomes of ACLR (Feucht et al., 2016; Heijne, Axelsson, Werner, & Biguet, 2008). Therefore, an effective clinician-patient relationship incorporating education on the requirements and importance of rehabilitation may improve patient motivation and adherence, increasing physiotherapy utilisation and the likelihood of an optimal outcome (Scott et al., 2018).

Although the number of ACC-funded physiotherapy treatments under a claim may provide an indication of the amount of rehabilitation the individual received, it cannot be assumed this accurately reflects their total rehabilitation. Other potential sources of rehabilitation include orthopaedic surgeons or other allied health professionals (Ebert, Webster, Edwards, Joss, D'Alessandro, et al., 2018), ACC-funded rehabilitation under VRS, non-clinically led rehabilitation (e.g. fitness trainer or gym instructor), privately funded physiotherapy or self-directed rehabilitation. Our results showed that for claims with approved VRS in the 12 months following ACL injury or surgery, the average number of physiotherapy treatments was very similar to claims without approved VRS, which indicates VRS had a negligible impact on the number of physiotherapy treatments per claim.

There is no clear evidence that supervised rehabilitation after ACLR will result in superior outcomes compared to minimally supervised rehabilitation (Anderson, Browning, Urband, Kluczynski, & Bisson, 2016; Lobb et al., 2012), which may have contributed to low physiotherapy treatment numbers in the current study. Selected groups of patients, including young, athletic people, may achieve acceptable outcomes after ACLR with a minimally supervised rehabilitation programme involving fewer than 10 physiotherapy treatments over three to 12 months (Feller, Webster, Taylor, Payne, & Pizzari, 2004; Grant & Mohtadi, 2010; Hohmann, Tetsworth, & Bryant, 2011).

Our results showed that over 70% of New Zealanders engaged in physiotherapy treatment after ACL injury, and over 90% engaged in physiotherapy after ACLR. Ebert, Edwards et al.

(2018) reported that 91% of people engaged in supervised rehabilitation/physiotherapy after ACLR, but 45% of people reported that rehabilitation following surgery lasted three months or less. Therefore, while the majority of people initially receive physiotherapy treatment following ACL injury or surgery, our results suggest people do not remain engaged in rehabilitation for an appropriate duration.

Although our results suggest possible underutilisation of physiotherapy-led services in the 12 months following ACL injury, an absence of outcome data means the relationship between utility and outcome is currently unknown. The New Zealand ACL Registry records outcome data for people undergoing ACLR (New Zealand ACL Registry, 2018), but as details regarding the type, amount or duration of rehabilitation received prior to or following surgery are unknown, it is not possible to correlate these outcomes with rehabilitation parameters. Although outcomes following ACLR may appear to be influenced by post-operative rehabilitation (Ebert, Edwards, et al., 2018; Edwards et al., 2018), these data were collected retrospectively, with participants subjectively grading the amount, type and duration of rehabilitation they received. As details of the post-ACLR rehabilitation were not quantified prospectively, it is possible they do not accurately reflect the rehabilitation received.

Time to surgery

Almost half of the Surgery Group proceeded to ACLR within 90 days of injury, and 80% within 180 days of injury. There is no accepted definition for early or delayed ACLR (Beynnon et al., 2005), with "early" defined as between two days and seven months of DOI, and "delayed" as between three weeks and 24 years (Anderson et al., 2016). There are equivocal differences in outcomes between patients undergoing early verses delayed ACLR (Anderson et al., 2016; Eriksson, von Essen, Jönhagen, & Barenius, 2018; Lee, Lee, Lee, & Hui, 2018; Smith, Postle, Penny, McNamara, & Mann, 2014; Wittenberg, Oxfort, & Plafki, 1998), although early surgical intervention may reduce the risk of subsequent meniscal or chondral injury, both of which are associated with worse outcomes following ACLR (Cinque et al., 2018; Cox et al., 2014).

Early ACLR is common practice both domestically (New Zealand ACL Registry, 2018) and internationally (Delay, Smolinski, Wind, & Bowman, 2001; Sanders, Maradit Kremers, Bryan, Kremers, et al., 2016). However, it can take at least six months following ACL injury for the true functional disability to be defined (Noyes, Matthews, Mooar, & Grood, 1983). A significant number of patients who may initially appear unable to cope with an ACL injury are able to cope following six months of rehabilitation (Moksnes, Snyder-Mackler, & Risberg, 2008). The time interval from ACL injury to ACLR may be less important as the condition of the knee at the time of surgery (Lattermann et al., 2018). Better pre-operative knee function is associated with fewer post-surgical complications and greater post-operative knee function (Beynnon et al., 2005; Filbay et al., 2017; Risberg et al., 2016). Therefore, treatment following ACL injury should involve physical rehabilitation to optimise functional ability before any decisions regarding surgical intervention are made (Eitzen et al., 2010; Thoma et al., 2019).

Subsequent ACL injury

Across all three groups, 11% of people had suffered multiple ACL injuries, which is slightly less than the overall rate for all ages (Wiggins et al., 2016). Younger people have a significantly higher rate of subsequent ACL injury after ACLR (Webster & Feller, 2016). Five percent of all people had suffered a previous ACL injury, and 2% went on to suffer a subsequent contralateral ACL injury. Following ACLR, graft rupture occurred in 5% of people, which is consistent with previously reported graft rupture rates (Crawford et al., 2013; Lai et al., 2017; van Yperen, Reijman, van Es, Bierma-Zeinstra, & Meuffels, 2018; Wright et al., 2011).

Limitations

No outcomes measures were collected for any clients – as this was not the purpose of the study – which limits the conclusions regarding the adequacy of the physiotherapy treatment received. No attempt was made to make comparisons between the groups or to make associations between variables, as without outcome data, these analyses would not offer any additional insights.

CONCLUSION

ACL injuries are a common injury in New Zealand, with ACC the primary funder of treatment for the condition. Rehabilitation following ACL injury can influence short- and long-term outcomes. Our results indicate the number of ACC-funded physiotherapy sessions and duration over time following ACL injury is highly variable. Possible reasons for this variability include financial barriers, a lack of patient understanding, a lack of endorsement of rehabilitation by the surgeon and the structure of the New Zealand healthcare system. No clinical or functional outcome data were collected in the current study, which limits the conclusions that could be drawn. However, when compared with previous research, our results indicate New Zealanders may not be accessing sufficient physiotherapy treatment following ACL injury. Future research should utilise validated measures to clarify outcomes from ACL injury in New Zealand. The use of such measures will allow for investigation into associations between patient outcomes and multiple variables along the ACL injury management pathway.

KEY POINTS

1. The number of physiotherapy treatments after ACL injury in New Zealand is highly variable and does not appear to meet best practice guidelines.
2. The effectiveness of physiotherapy treatment for ACL injury in New Zealand is unclear as patient outcomes from ACL injury in New Zealand have not been quantified.
3. Clearly defined patient reported outcome data will allow the effectiveness of physiotherapy and rehabilitation interventions to be determined.

DISCLOSURES

No funding was obtained for this study. Although ACC provided the data for analysis, ACC did not commission this research, and was not involved in the planning and conducting of this research. ACC was made aware of the study prior to its commencement and was fully supportive of the research.

Wayne Fausett and Fraser Wilkins are employees of ACC, but this research was not undertaken in their capacity as ACC employees. Wayne Fausett is a doctoral student at the Auckland University of Technology, and this research was completed as part of his coursework. All other authors report no conflicts of interest.

PERMISSIONS

Ethical approval was sought retrospectively. However, as advised by the Auckland University of Technology Ethics Committee, this study did not meet the threshold to require ethical approval as all data remained de-identified during collection and analysis.

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Appendix B.

The relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following primary anterior cruciate ligament reconstruction: a systematic review. Published in Physical Therapy Reviews.

PHYSICAL THERAPY REVIEWS
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The relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following primary anterior cruciate ligament reconstruction: a systematic review

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ABSTRACT

Background: Functional rehabilitation following anterior cruciate ligament reconstruction (ACLR) is often physiotherapist-led, and generally required to achieve patient goals. The quantity and duration of physiotherapist-led following could therefore potentially influence outcomes following ACLR, although the nature of this relationship is not clear.

Objective: To clarify the relationship between the quantity and duration of post-operative physiotherapy treatment and patient outcomes following ACLR.

Methods: A search of the PubMed/MEDLINE, Google Scholar, Cochrane Library, and EBSCO databases was made from inception to March 2021 to identify relevant studies. Key characteristics of the selected studies were extracted, with methodological quality evaluated using a modified version of the Downs and Black appraisal tool.

Results: The search strategy identified 1137 studies, 15 of which met inclusion criteria. Two studies were rated strong methodological quality, eight were rated moderate, and five were rated limited. Results across all 15 studies provided conflicting evidence regarding the effects of the quantity and duration of physiotherapy treatment on patient outcomes following ACLR.

Conclusions: Based on evidence of variable methodological quality, a clear relationship between the quantity and duration of physiotherapy treatment and patient outcomes following ACLR could not be established. Several themes were identified to guide future research in this area, including ensuring participant homogeneity, monitoring participant adherence to unsupervised rehabilitation, and utilising rehabilitation interventions that replicate everyday physiotherapy practice.

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ACL; Physiotherapy; outcomes; rehabilitation

Introduction

An anterior cruciate ligament (ACL) rupture is a devastating injury leading to a loss of structural knee stability and reduced functional ability in the short term, and decreased activity levels and an increased risk of knee osteoarthritis in the long-term [1–3]. The optimal management of an ACL rupture remains elusive, with multiple factors influencing whether the injury is managed conservatively or surgically [4]. ACL reconstruction (ACLR) is often considered necessary to reduce subsequent episodes of knee instability, permit a return to pre-injury activities, and preserve long-term knee joint health [5–7]. Despite increased knowledge of how to prevent ACL injuries [8], acceptable outcomes with conservative management [9], and a high incidence of subsequent ACL injury after ACLR [10], rates of ACLR have increased significantly in recent years [11–13].

Multiple factors can influence patient outcomes following ACLR, including, but not limited to, age, gender, concomitant injury, time from injury to surgery, and post-injury/ACLR rehabilitation [14–17]. Post-ACLR rehabilitation typically involves a significant functional component [18], although may also include psychological and vocational elements [19, 20]. The functional component typically includes exercises and activities to re-establish knee joint mobility, rebuild muscle strength, and optimise neuromuscular control [21, 22], followed by a graduated return to pre-injury activities [23].

With evidence-based clinical knowledge in rehabilitation and exercise therapy [24], physiotherapists possess the requisite skills to lead the functional component of an ACLR rehabilitation programme [25, 26]. Following ACLR, the quantity and duration of physiotherapy treatment is associated with an increased rate of return to sport [27–29], a decreased re-injury risk [30], greater self-reported knee function [31], and better performance

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on functional and clinical tests [17, 32]. Results are equivocal however, with studies also reporting the quantity and duration of post-ACLR physiotherapy treatment has no effect on knee strength [33], patient-reported outcomes [34], and re-injury rates [35].

Numerous patient reported outcome measures (PROMs) have been developed to evaluate outcomes following knee injury [36], with over 50 related to the ACL deficient knee alone [37]. PROMs provide an objective measure of an individual's subjective perception in relation to their functional status [38, 39]. The increasing use of PROMs to assess patient outcomes has realised the following benefits: increased patient-centred care, greater ability to establish treatment value, and improved patient outcomes [40]. Factors associated with superior patient reported outcomes following ACLR include younger age, male sex, not smoking, receiving a hamstring tendon autograft, and the absence of concomitant injuries [15].

Although physiotherapist-led rehabilitation following ACLR can have a positive effect on patient outcomes [41], the optimal dosage of post-ACLR physiotherapy treatment is currently unknown [42]. It is also not clear how the quantity and duration of post-ACLR physiotherapy treatment influences patient outcomes [43]. Therefore, the aim of this review is to determine the relationship between the quantity and duration of post-operative physiotherapy treatment and patient reported outcomes following primary ACLR.

Methods

Registration

This review was registered on 1/4/21 with the PROSPERO International Register for Systematic Reviews. The ID for this review is: CRD42021240112.

Information sources

Following advice from an experienced university librarian, a literature search was undertaken by the primary investigator (identifier removed for review process) using electronic databases accessible *via* the Auckland University of Technology library. Pubmed/MEDLINE, Google Scholar, Cochrane Library, Sportdiscus, AMED, and CINAHL were searched from inception to March 2021. Search terms used included: patient reported outcome measures, outcome, physiotherapy, "physical therapy", rehabilitation, ACL, "anterior cruciate ligament", "anterior cruciate ligament reconstruction", duration, quantity, supervis*, unsupervis*, "home based". Boolean operators were used to combine search terms. An example of the search strategy for PubMed is shown in Figure 1. Only full text studies published in English were selected. Reference lists of included studies were searched to identify any eligible studies that may have been missed during database searches.

Eligibility criteria

The following inclusion criteria were applied to select primary research studies relevant to the aim of this review:

1. Randomised controlled trials and non-randomised prospective cohort studies.
2. Participants had undergone primary ACLR.
3. Participants had received post-operative physiotherapy treatment.
4. Validated outcome data recorded prior to, and at the conclusion of, post-ACLR rehabilitation.

Studies were excluded if they met one of the following criteria:

1. Retrospective designs, single case studies, abstracts, and expert reviews.
2. Participants underwent revision ACLR.
3. The dosage of post-ACLR physiotherapy treatment could not be quantified.
4. Participants were less than 18 years of age.
5. Participants had significant concomitant knee injury e.g. multi-ligament rupture, fracture, joint dislocation.

Study selection and data collection

Once databases searches were complete, all results were either included or excluded for review in accordance with the PRISMA study selection process for systematic reviews [44]. After duplicates were removed, titles and abstracts of remaining studies were screened for relevance by one reviewer (WF). The full texts of articles that appeared relevant to the aim of the review were retrieved and independently screened by two reviewers (WF and DR). with inclusion and exclusion criteria subsequently applied. Any discrepancies regarding study selection were resolved by consensus discussion, with involvement of a third researcher (PL) if required.

Data was extracted from the selected studies by the lead author (identifier removed for review process) and tabulated under the following headings: (1) study type, (2) participant demographics, (3)

Search	Actions	Details	Query	Results
#21	•••	›	Search: **#11 AND #12 AND #13 AND #19 AND #20** Sort by: **Publication Date**	10
#20	•••	›	Search: **#16 OR #17 OR #18** Sort by: **Publication Date**	94,629
#19	•••	›	Search: **#1 OR #15** Sort by: **Publication Date**	1,973,391
#18	•••	›	Search: **"home based"[Title/Abstract]** Sort by: **Publication Date**	12,223
#17	•••	›	Search: **unsupervis*[Title/Abstract]** Sort by: **Publication Date**	14,364
#16	•••	›	Search: **supervis*[Title/Abstract]** Sort by: **Publication Date**	73,274
#15	•••	›	Search: **outcome*[Title/Abstract]** Sort by: **Publication Date**	1,973,391
#14	•••	›	Search: **#1 AND #11 AND #12 AND #13** Sort by: **Publication Date**	0
#13	•••	›	Search: **#9 OR #10** Sort by: **Publication Date**	725,572
#12	•••	›	Search: **#6 OR #7 OR #8** Sort by: **Publication Date**	26,002
#11	•••	›	Search: **#3 OR #4 OR #5** Sort by: **Publication Date**	217,454
#10	•••	›	Search: **quantity[Title/Abstract]** Sort by: **Publication Date**	91,189
#9	•••	›	Search: **duration[Title/Abstract]** Sort by: **Publication Date**	637,769
#8	•••	›	Search: **"anterior cruciate ligament reconstruction"[Title/Abstract]** Sort by: **Publication Date**	7,687
#7	•••	›	Search: **"anterior cruciate ligament"[Title/Abstract]** Sort by: **Publication Date**	20,602
#6	•••	›	Search: **ACL[Title/Abstract]** Sort by: **Publication Date**	18,283
#5	•••	›	Search: **rehabilitation[Title/Abstract]** Sort by: **Publication Date**	183,432
#4	•••	›	Search: **"physical therapy"[Title/Abstract]** Sort by: **Publication Date**	23,256
#3	•••	›	Search: **physiotherapy[Title/Abstract]** Sort by: **Publication Date**	22,070
#1	•••	›	Search: **"patient reported outcome measures"[Title/Abstract]** Sort by: **Publication Date**	6,433

Figure 1. Example of the search strategy for PubMed.

intervention, (4) control, (5) outcome measures, (6) results.

Risk of bias assessment

Included studies were independently analysed by two reviewers (identifiers removed for review process) using a modified Downs and Black checklist. Any discrepancies were resolved *via* collective scientific debate, which included a third reviewer if necessary (identifier removed for review process). The modified Downs and Black checklist consists of 27 questions, with a maximum possible score of 28 points. The lower the overall score, the lower the methodological quality of the study. There are 4 sections, which look at reporting (x/11), external validity (x/3), internal validity (bias) (x/7) and internal validity–confounding (selection bias) (x/6) of a study. The final question relates to the overall power of the study (x/1). As utilised in previous systematic reviews [45, 46], the last question was modified from the original version, which had a score out of five, to a score out of one, with one point being awarded if a calculation of the study's power was included. As per previous systematic reviews [45, 46], a quality index was calculated, with studies rated as having strong, moderate, limited, or poor methodological quality (Table 1).

Results

Study selection

The literature search identified 1137 records, with 15 studies meeting the inclusion criteria (Figure 2). Physiotherapy treatment data was then extracted from the 15 studies, which were divided into two groups – studies reporting the effects of the *Quantity* of post-ACLR physiotherapy treatment on patient outcomes ($n = 11$), and studies reporting the

Table 1. Quality index scores.

Total score modified Downs and Black checklist (/28)	Percentage of total score	Quality index
21+	75%+	Strong
14–20	50–74%	Moderate
7–13	25–49%	Limited
<7	<25%	Poor

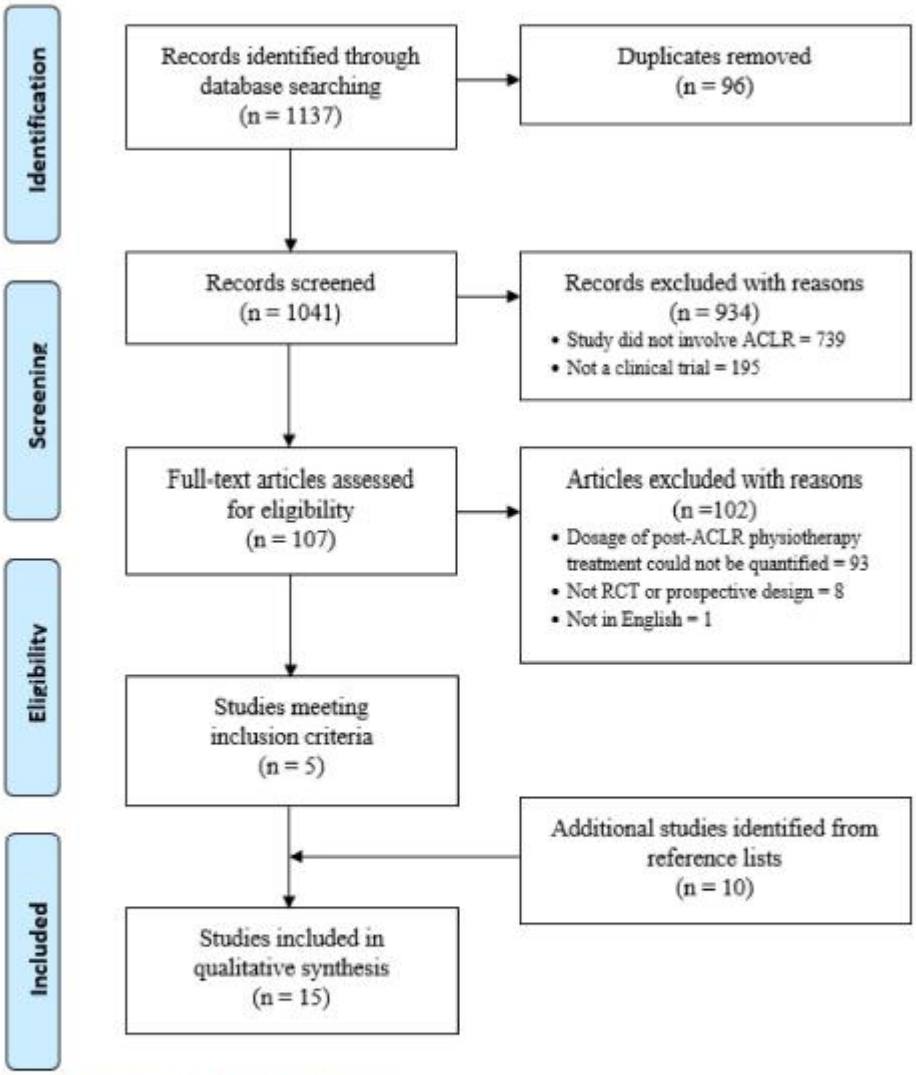

Figure 2. PRISMA flow diagram of study selection process.

effects of the *Duration* of post-ACLR physiotherapy treatment on patient outcomes ($n = 4$).

Study characteristics

The 11 *Quantity* studies consisted of nine randomised controlled trials (RCTs) and two prospective cohort studies (Table 2). The four *Duration* studies consisted of two RCTs and two prospective cohort studies (Table 3).

Participants

For *Quantity* studies, participant numbers ranged from 26 [47, 48] to 145 [49], with the total number of participants being 651 (30% female) (Table 2). The average age of participants across the 22 study groups was 28 years (range 21–39 years). Eight of 11 *Quantity* studies reported an average time between ACL injury and ACLR, which ranged from less than 12 weeks to 52 months, with one study reporting up

Table 2. Characteristics of selected studies reporting the effects of the quantity of physiotherapy treatment on patient outcomes following ACLR.

Author/Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
(Schenck et al., 1997) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Average age of all subjects = 24 Subject activity level = Recreational athletes Time from ACL injury to ACLR = not stated Subjects: *N* = 37 (9 female) Clinic-based rehabilitation group *N* = 15 Home-based rehabilitation group *N* = 22	Clinic-based group Completed clinic-based functional rehabilitation Average number of PT treatments = 14 (range 6-40) Home-based group Completed an exercise-based functional program, monitored by a PT as required Average number of PT treatments = 3 (range 0-6)	None	1. Knee joint ROM 2. Knee joint laxity 3. Lysholm score 4. VAS pain scale 5. Sickness Impact Profile questionnaire 6. Single-leg hop for distance Average follow-up was 21.6 months (range 12 to 48 months)	No difference between Home-based rehabilitation versus Clinic-based rehabilitation for all outcomes	Total score x/28 = 8 Quality Index = 29% Quality Index Category = Limited
(Beard & Dodd, 1998) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Subject activity level = not stated Home-based rehabilitation group *N* = 13 (3 female) Average age at ACLR = 27 Average time from ACL injury to ACLR = 47 months Supervised rehabilitation group *N* = 13 (2 female) Average age at ACLR = 29 Average time from ACL injury to ACLR = 52months	All subjects completed same rehabilitation for first 4-6 weeks post-ACLR, then randomised to either Supervised or Home-based rehabilitation group Supervised group Performed an identical programme to the Home-based group, but also attended a supervised PT-led exercise class twice weekly. Median number of classes attended = 16 (range 10-22) out of a possible 32 Home-based group Performed rehabilitation exercises either at home or using commercial/private facilities. Attended the PT department for assessment, education, modification, and	None	1. IKDC score 2. Lysholm score 3. Tegner activity score 4. VAS for sports participation and activities of daily living 5. Isokinetic strength of the thigh muscles 6. Passive anterior sagittal translation of the knee joint Outcome measures recorded pre-ACLR, and 3- and 6-months post-ACLR	No difference between Home-based rehabilitation versus Supervised rehabilitation for all outcomes	Total score x/28 = 20 Quality Index = 71% Quality Index Category = Moderate

(*continued*)

Table 2. Continued.

Author/Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
		progression of rehabilitation programme				
(Fischer et al., 1998) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Time from ACL injury to ACLR for all subjects ranged from 1.5 to 216 months Subject activity level = not stated Home-based rehabilitation group *N* = 27 (11 female) Average age at ACLR = 32 Clinic-based rehabilitation group *N* = 27 (14 female) Average age at ACLR = 27	Home-based group Prescribed 6 PT treatments in the first 12 weeks post-ACLR – subjects averaged 5 (range 3-7) PT treatments Clinic-based group Subjects averaged 20 (range 10-28) PT treatment sessions	None	6/12/24 weeks Knee ROM Thigh girth Manual tests for knee stability Knee joint laxity 12/24 weeks Lysholm score 24 weeks Hop test battery (1-leg hop for distance, timed 6-metre hop, triple hop for distance, triple slalom hop for distance) HSQ	No difference between Home-based rehabilitation versus Clinic-based rehabilitation for all outcomes	Total score x/28 = 17 Quality Index = 61% Quality Index Category = Moderate
(Grant et al., 2005) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Subject activity level = not stated Home based rehabilitation group *N* = 73 (26 female) Average age at injury = 26 Average time from ACL injury to ACLR = 17 months Supervised rehabilitation group *N* = 72 (34 female) Average age at injury = 26 Average time from ACL injury to ACLR = 20 months	Home-based group Subjects averaged 3 ± 1 (range 0-8) PT treatment sessions following ACLR Supervised group Subjects averaged 14 ± 4 (range 2-20) PT treatment sessions following ACLR	None	1. ACL-QOL questionnaire 2. Knee joint ROM 3. Knee joint ROM during walking 4. Knee joint laxity 5. Isokinetic quadriceps and hamstrings strength All outcome measures recorded 6- and 12-weeks post-ACLR	Higher percentage of patients in Home-based rehabilitation group recorded acceptable knee joint ROM at 12-week follow up No difference between Home-based rehabilitation versus Supervised rehabilitation for ROM during walking, joint laxity, and knee strength at 12-week follow-up	Total score x/28 = 25 Quality Index = 89% Quality Index Category = Strong
(Ugutmen et al., 2008) Randomised controlled trial	All subjects underwent arthroscopic ACLR with hamstring graft Gender Male = 103 Female = 1	All subjects received weekly instruction on exercises for 6 weeks post-ACLR Home-based group Subjects seen 14 times by physiotherapists and the	None	1. Hospital of Spedal Surgery score 2. IKDC score 3. Lysholm score 4. Thigh atrophy 5. Knee joint laxity 6. Knee joint ROM	No difference between Home-based rehabilitation versus Clinic-based rehabilitation for all outcomes	Total score x/28 = 10 Quality Index = 36% Quality Index Category = Limited

(*continued*)

Table 2. Continued.

Author/Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
	Average age of all subjects = 31.5 years Average time between ACL injury and ACLR for all subjects = 34.3 months (range 2-144 months) Subject activity level = not stated Home-based rehabilitation group *N* = 52 Clinic-based rehabilitation group *N* = 52	orthopaedic surgeon for physical examination and measurements Clinic-based group Number of PT treatments not stated		7. Clinical tests for knee stability 8. VAS pain scale Average follow-up time = 31.1 months (range 12-66 months).		
(Revenäs et al., 2009) Randomised controlled trial	Subjects underwent arthroscopic bone-patella tendon-bone or hamstring tendon ACLR Guided Therapy group *N* = 27 (11 female) Average age = 24 (16-40) Subjects with pre-injury Tegner score 9-10 = 52% Average time from ACL injury to ACLR = 22 months (range 4-177) Knee Class group *N* = 24 (7 female) Average age = 21 (16-39) Subjects with pre-injury Tegner score 9-10 = 67% Average time from ACL injury to ACLR = 9 months (range 3-44)	Guided Therapy group Individual rehabilitation programme at least 2 x weekly, from 7-24 weeks post-ACLR, with PT review as required Median number of PT visits = 3 (range 0-8) Knee Class group Individual rehabilitation programme at least 2 x weekly, plus PT-led Knee Class 2 x weekly from 7-24 weeks post-ACLR Median number of Knee Class visits = 15 (range 13-36)	None	1. IKDC score 2. Lysholm score 3. Tegner activity score 4. Isometric quadriceps strength 5. Single leg hop for distance 6. Knee joint ROM Outcome measures recorded 6- and 12-months post-ACLR	Guided Therapy rehabilitation group reported higher Lysholm score at 6-month follow-up Guided Therapy rehabilitation group reported greater increase in Lysholm score at 12-month follow-up Knee Class rehabilitation group reported higher Tegner activity score at 12-month follow-up Non-compliant subjects in Knee Class rehabilitation group reported greater change in Lysholm score than compliant subjects	Total score x/28 = 20 Quality Index = 71% Quality Index Category = Moderate
(Grant & Mohtadi, 2010) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Subject activity level = not stated	Home-based group Subjects averaged 3 ±1 (range 0-8) PT treatment sessions following ACLR Supervised group	None	1. ACL-QOL questionnaire 2. IKDC score 3. Knee joint ROM 4. Knee joint laxity	Home-based rehabilitation group reported significantly higher ACL-QOL scores No difference between	Total score x/28 = 26 Quality Index = 93% Quality Index Category = Strong

(*continued*)

Table 2. Continued.

Author/Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
	Home based rehabilitation group *N* = 40 (13 female) Average age at injury = 26 Average time from ACL injury to ACLR = 17 months Supervised rehabilitation group *N* = 48 (25 female) Average age at injury = 26 Average time from ACL injury to ACLR = 20 months	Subjects averaged 14 ± 4 (range 2-20) PT treatment sessions following ACLR		5. Isokinetic quadriceps and hamstrings strength Outcome measures recorded at an average of 38 months (range 26-52) post-ACLR	Home-based rehabilitation versus Supervised rehabilitation for IKDC score, ROM, joint laxity, or quadriceps and hamstrings strength	
(Hohmann et al., 2011) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR Subject activity level = "physically active" Supervised rehabilitation group *N* = 20 (4 female) Average age at injury = 28 Average time from ACL injury to ACLR = <3 months Home based rehabilitation group *N* = 20 (6 female) Average age at injury = 27 Average time from ACL injury to ACLR = <3 months	Supervised group Prescribed 18 PT sessions following ACLR Home-based group Subjects given handout with rehabilitation protocol following ACLR, with no PT sessions prescribed.	None	1. Lysholm score 2. Tegner activity score 3. Isokinetic quadriceps and hamstring strength 4. Hop test battery (single hop for distance, timed hop and vertical jump) All outcome measures recorded pre-ACLR, then 3-, 6-, 9-, and 12-months post-ACLR	Home-based rehabilitation group recorded greater isometric knee extensor strength at 3-month follow-up Supervised rehabilitation group recorded greater isokinetic knee extensor strength at 6-month follow-up No difference between Home-based rehabilitation versus Supervised rehabilitation for Lysholm score, Tegner activity score, and hop test battery.	Total score x/28 = 19 Quality Index = 68% Quality Index Category = Moderate
(Lim et al., 2019) Randomised controlled trial	All subjects underwent arthroscopic ACLR with hamstring graft Subject activity level = not stated Supervised rehabilitation group *N* = 15 (5 female) Average age = 32 Average time from ACL injury to ACLR = >3 months Home based rehabilitation group *N* = 15 (6 female)	Supervised group Prescribed 44 PT-supervised rehabilitation sessions post-ACLR. No home-based exercises performed Home-based group Advised to complete rehabilitation exercises twice per week following ACLR. Weekly follow-up with physiotherapist *via* phone	None	1. Isokinetic quadriceps and hamstring strength 2. Proprioception (Biodex Stability System) Outcome measures recorded pre-ACLR and 24 weeks post-ACLR	No difference between Home-based rehabilitation versus Supervised rehabilitation for quadriceps and hamstring strength Supervised rehabilitation group recorded increase in proprioception	Total score x/28 = 18 Quality Index = 64% Quality Index Category = Moderate

(*continued*)

Table 2. Continued.

Author/Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
	Average age = 39 Average time from ACL injury to ACLR = >3 months					
(Przybylak et al., 2019) Prospective cohort – non-randomised	Hamstring tendon ACLR *N* = 39 Bone-patella tendon-bone ACLR *N* = 11 Subject activity level = Amateur recreational athletes Supervised rehabilitation group *N* = 25 (7 female) Average age = 34 Average time from ACL injury to ACLR = >6 months Home-based rehabilitation group *N* = 25 (6 female) Average age = 27 Average time from ACL injury to ACLR = >6 months	Supervised group Prescribed 46 PT-supervised rehabilitation sessions following ACLR Home-based group Prescribed 5 PT-supervised rehabilitation sessions following ACLR	None	1. Kujala Anterior Knee Pain Questionnaire 2. Tegner activity score 3. KOOS 4. Knee Joint ROM 5. Functional Movement Screen Outcome measures recorded pre-ACLR and 12-months post-ACLR	Supervised rehabilitation group reported greater increases in the KOOS Symptoms, QoL, and Sport subscales, Tegner score, and Functional Movement Screen score	Total score x/28 = 13 Quality Index = 46% Quality Index Category = Limited
(Rhim et al., 2021) Prospective cohort – non-randomised	All subjects underwent arthroscopic ACLR with hamstring graft Subject activity level = not stated Time from ACL injury to ACLR = not stated Supervised rehabilitation group *N* = 13 (3 female) Average age = 27 years Home-based rehabilitation group *N* = 13 (4 female) Average age = 29 years	Supervised group Subjects received 12 PT treatments in the first 12 weeks post-ACLR, then bi-weekly treatments at the discretion at the PT for an unspecified duration Home-based group Subjects received instruction on post-ACLR rehabilitation exercises as an in-patient, and then underwent PT review at 2, 6, 12, and 24 weeks post-ACLR	None	1. Isokinetic quadriceps and hamstring strength 2. Dynamic postural stability (Biodex Stability System) 3. Lysholm score All outcome measures recorded pre-ACLR, and 6- and 12-months post-ACLR	Supervised rehabilitation group recorded greater hamstring strength at 12-month follow-up Supervised rehabilitation group demonstrated greater postural stability at 6- and 12-month follow-up Supervised rehabilitation group reported higher Lysholm scores at 12-month follow-up	Total score x/28 = 17 Quality Index = 61% Quality Index Category = Moderate

Abbreviations: ACLR = anterior cruciate ligament reconstruction; VAS = visual analogue scale; IKDC = International Knee Documentation Committee; PT = physiotherapy/st; KOOS = Knee Injury and Osteoarthritis Outcome Score; ROM = range of motion; QOL = quality of life; VAS = visual analogue scale; HSQ = Health Status Questionnaire.

to an 18-year interval between ACL injury and ACLR for some participants [50].

For *Duration* studies, participant numbers ranged from 22 [51] to 60 [52], with the total number of participants being 173 (14% female) (Table 3). The average age of participants across the 10 study groups was 28 years (range 23–35 years). The average time from ACL injury to ACLR ranged from 56 days to 33 weeks, with one study not reporting the time between ACL injury and ACLR [53].

No *Quantity* study reported an objective measure of pre-injury activity level for participants. Two of four *Duration* studies reported a pre-injury activity level for participants, with Tegner Activity Scale score ranging from five to eight [51, 52].

Interventions

Rehabilitation interventions for the *Quantity* studies are summarised in Table 2. The average number of post-ACLR physiotherapy treatments for the lesser treatment groups was 3 (range 0-14). Four studies did not clearly report the duration of physiotherapy treatment for the lesser treatment group. The average number of post-ACLR physiotherapy treatments for the greater treatment groups was 21 (range 12-46).

Rehabilitation interventions for the *Duration* studies are summarised in Table 3. Post-ACLR physiotherapy treatment duration across all study groups ranged from 8 to 19 weeks for shorter duration groups and from 27 to 32 weeks for longer duration groups. In both studies by Beynnon and colleagues, where participants in the 19- and 32-week groups completed the same rehabilitation programme, the 19-week group completed the same volume of rehabilitation in a shorter time [51, 54]. In both studies by Królikowska and colleagues, participants in the shorter duration groups elected to discontinue physiotherapist-supervised rehabilitation but were advised to continue with home-based rehabilitation [52, 53].

Controls

None of the 11 *Quantity* studies included a control group, with all studies comparing results between groups of participants receiving different quantities of post-ACLR physiotherapy treatment (Table 2). Two *Duration* studies included a control group where participants had not undergone ACLR and received no rehabilitation, with two studies comparing results between groups of participants undergoing post-ACLR physiotherapy treatment of different durations (Table 3).

Methodological quality

The methodological quality and Quality Index (% and categorisation) of the *Quantity* and *Duration* studies are presented as tables in Appendices 1 and 2 respectively. For *Quantity* studies, the average quality score was 17/28 (range 8-26), with an average Quality Index of 63% (range 21-93%). Regarding methodological quality, two studies rated 'strong', six rated 'moderate', and three rated 'limited'. Scores ranged from 3-11/11 in the Reporting section, from 0-3/3 in the External Validity section, from 2-6/7 in the Internal Validity (Bias) section, and from 1-6/6 in the Internal Validity (Confounding) section. Only six of 11 *Quantity* studies reported a power analysis.

For *Duration* studies, the average score was 15/28 (range 10-20), with an average Quality Index of 53.5% (range 36-71%). Two studies rated 'moderate' methodological quality and two rated 'limited' methodological quality. Scores ranged from 8-10/11 in the Reporting section, from 0-1/3 in the External Validity section, from 3-5/7 in the Internal Validity (Bias) section, and from 2-6/6 in the Internal Validity (Confounding) section. Two of four *Duration* studies reported a power analysis.

Outcomes

A wide range of patient-reported, clinical, and functional outcome measures were used in the *Quantity* studies (Table 2). For patient-reported outcome measures, two studies reported a positive effect for a greater quantity of physiotherapy treatment [48, 55], one study reported a positive effect for a lesser quantity of treatment [56], and one study reported a positive effect for both greater and lesser quantities of physiotherapy treatment [57]. For clinical outcome measures, two studies reported a positive effect for a greater quantity of physiotherapy treatment [48, 58], one study reported a positive effect for less treatment [49], and one study reported a positive effect for both greater and lesser quantities of physiotherapy treatment [59]. For functional outcome measures, two studies reported a positive effect for a greater quantity of physiotherapy treatment [48, 55]. Four studies reported the quantity of post-ACLR physiotherapy treatment had no significant effect on any outcome measure [47, 50, 60, 61]. Average follow up periods across all *Quantity* study groups ranged from 12 weeks [49] to 38 months [56].

A range of patient-reported, clinical, and functional outcome measures were also used in the *Duration* studies (Table 3). The duration of post-ACLR physiotherapy treatment had no effect on patient-reported outcome measures (IKDC, KOOS,

Table 3. Characteristics of selected studies reporting the effects of the duration of physiotherapy treatment on patient outcomes following ACLR.

Author/Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
(Beynnon et al., 2005) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR. Subject activity level = Moderately active (Pre-injury Tegner score = ≥5) Accelerated rehabilitation group *N* = 10 (5 female) Average age at ACLR = 30 Average time from ACL injury to ACLR = 91 days Non-accelerated rehabilitation group *N* = 12 (6 female) Average age at ACLR = 35 Average time from ACL injury to ACLR = 124 days	Both groups attended supervised rehabilitation sessions with a PT 3x/week and performed home exercises on other days Both rehabilitation programmes included the same exercises/activities Accelerated group Post-ACLR rehabilitation lasted 19 weeks Non-accelerated group Post-ACLR rehabilitation lasted 32 weeks	None	1. IKDC score 2. KOOS 3. Tegner activity score 4. Knee joint laxity 5. Single leg hop for distance Outcome measures recorded at 3-, 6-, 12- and 24-months post-ACLR	No difference between Accelerated rehabilitation versus Non-accelerated rehabilitation for all outcomes	Total score x/28 = 19 Quality Index = 68% Quality Index Category = Moderate
(Beynnon et al., 2011) Randomised controlled trial	All subjects underwent arthroscopic bone-patella tendon-bone ACLR. Subject activity level = not stated Accelerated rehabilitation group *N* = 19 (6 female) Average age at ACLR = 30 Average time from ACL injury to ACLR = 56 days Non-accelerated rehabilitation group *N* = 17 (8 female) Average age at ACLR = 30 Average time from ACL injury to ACLR = 66 days	Both groups attended supervised rehabilitation sessions with a PT 3x/week and performed home exercises on other days. Both groups competed the same volume of post-ACLR rehabilitation Accelerated group Post-ACLR rehabilitation lasted 19 weeks Non-accelerated group Post-ACLR rehabilitation lasted 32 weeks	None	1. IKDC score 2. KOOS 3. Tegner activity score 4. Knee joint laxity 5. Single leg hop for distance 6. Isokinetic quadriceps and hamstrings strength 7. Proprioception Outcome measures recorded pre-ACLR, then at 3-, 6-, 12- and 24-months post-ACLR	Accelerated rehabilitation group recorded greater quadriceps strength at 3-month follow-up No difference between Accelerated rehabilitation versus Non-accelerated rehabilitation for all other outcomes	Total score x/28 = 20 Quality Index = 71% Quality Index Category = Moderate
(Królikowska et al., 2018) Prospective cohort – non-randomised	All subjects in Groups 1 and 2 underwent arthroscopic ACLR with hamstring graft	Group 1 Average of 28 weeks PT-supervised rehabilitation post-ACLR	Group 3 No rehabilitation	1. Vertical ground reaction force during one- and two-legged vertical jumps	Group 1 recorded greater limb symmetry during two-legged vertical jump compared to Group 2	Total score x/28 = 10 Quality Index = 36% Quality Index Category = Limited

(*continued*)

Table 3. Continued.

Author/Study Type	Participant Demographics	Intervention	Control	Outcome Measures	Results	Downs and Black Quality Assessment
	Subject activity level = not stated Group 1 N = 20 (0 female) Average age = 26 Average time from ACL injury to ACLR = not reported Group 2 N = 15 (0 female) Average age = 27 Average time from ACL injury to ACLR = not reported Group 3 N = 20 (0 female) Average age = 23 No known orthopaedic problems	Group 2 Average of 11 weeks PT-supervised rehabilitation post-ACLR, then continued with home-based, unsupervised rehabilitation Compliance/adherence to home-based rehabilitation not recorded		Group 1 Final evaluation at 28 weeks post-ACLR Group 2 Final evaluation at 32 weeks post-ACLR		
(Królikowska et al., 2018) Prospective cohort – non-randomised	All subjects in Groups 1 and 2 underwent arthroscopic ACLR with hamstring graft Subject activity level = Pre-injury Tegner activity score >4 and <9 Group 1 N = 15 (0 female) Average age = 25 Average time from ACL injury to ACLR = 33 weeks Group 2 N = 15 (0 female) Average age = 28 Average time from ACL injury to ACLR = 33 weeks Group 3 N = 30 (0 female) Average age = 25 No known orthopaedic problems	Group 1 Average of 27 weeks of PT-supervised rehabilitation following ACLR Group 2 Average of 8 weeks of PT-supervised rehabilitation following ACLR, then continued with home-based, unsupervised rehabilitation Compliance/adherence to home-based rehabilitation not recorded	Group 3 No rehabilitation	1. IKDC score 2. Knee joint circumference 3. Thigh circumference 4. Knee joint ROM 5. VAS pain scale 6. Agility run test Group 1 Final evaluation 27 weeks post-ACLR Group 2 Final evaluation 33 weeks post-ACLR	Group 2 recorded worse performance on agility run test than Groups 1 and 3 Duration of supervised rehabilitation significantly correlated with agility run test performance	Total score x/28 = 11 Quality Index = 39% Quality Index Category = Limited

Abbreviations: ACL = anterior crudate ligament; ACLR = anterior crudate ligament reconstruction; VAS = visual analogue scale; IKDC = International Knee Documentation Committee; PT = physiotherapist; KOOS = Knee Injury and Osteoarthritis Outcome Score; ROM = range of motion.

Table 4. Overall levels of evidence.

Level of Evidence	Requirement
Strong	Consistent findings among multiple high quality randomised controlled trials (RCTs)
Moderate	Consistent findings among multiple low quality RCTs and/or case-controlled trials (CCTs) and/or one high quality RCT
Limited	One low quality RCT and/or CCT
Conflicting	Inconsistent findings among multiple trials (RCTs and/or CCT)

Tegner score, VAS pain score). A longer duration of physiotherapy treatment had a positive effect on functional outcomes (vertical jump performance, agility run performance) [52, 53] and clinical outcomes (quadriceps strength, thigh circumference) [52, 54]. Follow up periods across all *Duration* study groups ranged from 27 weeks [52] to 24 months [51, 54].

Strength of evidence

Meta-analysis was not possible due to the heterogeneity of the selected studies. A synthesis of the overall evidence was therefore performed using the criteria described in Table 4 [62].

For *Quantity* studies, the two studies rated 'strong' methodological quality either reported superior outcomes for a group of ACLR patients receiving a lower number of physiotherapy treatments compared to a group receiving a higher number, or no difference in outcomes between the groups. Of the six studies rated 'moderate' methodological quality, two reported the quantity of post-ACLR physiotherapy treatment had no effect on patient outcomes, two reported the quantity of post-ACLR physiotherapy treatment had conflicting effects on patient outcomes, and two reported the quantity of post-ACLR physiotherapy treatment had a positive effect on patient outcomes. Of the three studies rated 'limited' methodological quality, one reported the quantity of post-ACLR physiotherapy treatment had a positive effect on patient outcomes, and two reported the quantity of post-ACLR physiotherapy treatment had no effect on patient outcomes. Overall, the level of evidence for the *Quantity* studies is best described as 'Conflicting' [62].

For *Duration* studies, the two studies rated 'moderate' methodological quality reported the duration of post-ACLR physiotherapy treatment had no effect on patient outcomes. The two studies rated 'limited' methodological quality reported a longer duration of post-ACLR physiotherapy treatment was associated with better patient outcomes. Overall, the level of evidence for the *Duration* studies is best described as 'Conflicting' [62].

Discussion

Summary of main findings

The literature search identified 15 articles where post-ACLR physiotherapy treatment data could be extracted from and used to determine the relationship between the quantity and duration of physiotherapy treatment and patient outcomes following ACLR. Based on the findings of the selected studies, it is not clear if the quantity and duration of physiotherapy treatment significantly influences patient outcomes following ACLR. Considerable heterogeneity in the methodologies of the selected studies regarding sample size, time from ACL injury to ACLR, the dosage of post-ACLR physiotherapy treatment, outcome measures used, and final evaluation timeframes likely contributed to the inconclusive findings.

Comparison to existing literature

Previous systematic reviews have reported the quantity of physiotherapy supervision during post-operative rehabilitation following ACLR does not significantly influence patient outcomes [21, 22, 42, 63–66]. All seven reviews included at least three studies from the current review, and all highlighted significant methodological inadequacies in the selected studies, including small sample sizes, absence of sample size calculation, inadequate randomisation, non-blinding of assessors, gender bias, and no reporting of compliance.

As part of wider systematic reviews on post-operative rehabilitation following various knee surgeries, a clear benefit of supervised rehabilitation over unsupervised/home-based rehabilitation following ACLR could not be established [67, 68]. A recent scoping review on the frequency and duration of supervised rehabilitation following ACLR, which included 11 of the 15 studies from the current review, concluded moderately or minimally supervised rehabilitation is at least as effective as fully supervised high-frequency rehabilitation, and at least 6 months of supervised rehabilitation is associated with more favourable outcomes after ACLR [43].

Several inconsistencies were noted between previous reviews and the current review regarding assessment of methodological quality for selected studies. For example, the study by Grant et al. (2010) was scored 4/10 by Gamble et al. (2021), indicating a lower quality study, but the current review scored Grant et al. (2010) at 93%, indicating a high-quality study. The study by Ugutmen et al. (2008) scored 90/100 by Papalia et al. (2013), which suggests a low risk of bias, whereas the Quality Index of Ugutmen

et al. (2008) in the current review was scored as 36%, which suggests a high risk of bias. As different quality assessment tools assess different biases [69], whichever tool is chosen to assess the methodological quality of selected studies has the potential to significantly influence the overall findings of the review.

Nine of the 11 *Quantity* studies compared clinic-based, physiotherapy-led rehabilitation with home-based rehabilitation. The average quantity and duration of physiotherapy for clinic-based rehabilitation and home-based rehabilitation was 21 treatments over 26 weeks and 4 treatments over 25 weeks respectively. In the 12 months following ACLR in New Zealand, patients receive an average of 10-12 physiotherapy treatments, over an average duration of 143-161 days [20]. The majority of Flemish physical therapists use 41-60 treatments over 6-7 months following ACLR [70]. Therefore, the quantity and duration of physiotherapy treatment in the selected studies may not be an accurate reflection of everyday physiotherapy practice. To increase external validity, future research on ACLR rehabilitation should include interventions that replicate usual physiotherapy practice.

In the first 12 weeks following ACLR, 25-38 rehabilitation sessions have been recommended [23], with a physiotherapist review at least every two weeks to ensure adequate progress is maintained [26]. Up to 35 physiotherapy treatments may be required in the 12 months following ACLR [20]. The optimal frequency of rehabilitation supervision has yet to be determined [43], and the number of physiotherapy treatments required is likely dependent on the progress of the individual patient [26].

Results from this review, and previous reviews, suggest there is no singular optimal dosage of physiotherapy treatment following ACLR that can be applied to all patients. Contemporary ACLR rehabilitation is now less prescriptive, with progress through rehabilitation determined by the patient's achievement of functional milestones, not time from surgery [42, 71]. Similarly, the dosage of post-ACLR physiotherapy treatment should also not be predetermined, but instead be the end-product the quantity and duration of treatment required for the patient to achieve their post-operative goals [26].

Other person-related factors, such as age, gender, activity levels, and concomitant injury at ACLR potentially have a greater effect on post-operative outcomes than the dosage of physiotherapy treatment. The average age of participants across all 15 studies in the current review was 28 years, with 27% of participants female. Outcomes for patients over 30 years of age, and for female patients, are typically worse following ACLR [15, 72]. Therefore, a high percentage of male participants, and participants under 30 years of age, in a sample could result in an artificially high number of participants achieving better outcomes. However, a significant percentage of ACL injuries occur in females and in people over 30 years of age [73]. Therefore, future ACL research should ensure a distribution of participants related to age and gender that represents of the current demographic of ACL injury.

A higher activity level prior to ACL injury is associated with a higher activity level following ACLR [74]; however, it is not clear if patient activity level influences the dosage of physiotherapy treatment required following ACLR. Elite athletes may require more advanced rehabilitation and a greater level of supervision than recreational athletes, or conversely, elite athletes may possess a higher level of motivation to complete rehabilitation, leading to a lesser need for supervision [66]. For multiple reasons, including the dosage of post-ACLR physiotherapy, a greater percentage of elite athletes return to pre-injury activity levels compared to non-elite athletes [75]. Future research should investigate the dosage of physiotherapy required to achieve acceptable outcomes in ACLR patients who encompass the spectrum of activity levels.

Across 13 of the 15 studies in the current review, the time between ACL injury and ACLR ranged from 56 days to 18 years, with two studies not reporting a time [48, 60]. A longer time to ACLR is associated with an increased risk of secondary meniscal and chondral injury due to recurrent instability episodes [76, 77], and the presence of meniscal or chondral injury at the time of ACLR is associated with worse patient outcomes [78, 79]. Therefore, a longer time between injury and ACLR could negatively influence patient outcomes. Only seven of 15 studies in the current review reported excluding participants with concomitant meniscal or chondral injuries at the time of ACLR, which, when combined with the wide range of times between injury and surgery, could have influenced the results of the studies in this review.

Overall, findings from the current review add to the previous literature that indicates the quantity and duration of physiotherapy treatment following ACLR does not appear to significantly influence post-operative outcomes. Previous reviews have focused on the level of supervision during post-ACLR rehabilitation, or home-based verses clinic-based rehabilitation, than the actual quantity and duration of physiotherapy treatment. The current review is therefore unique, as it is the first review to specifically address the quantity and duration of physiotherapy treatment following ACLR.

Quality of selected studies

The average Downs and Black score for all studies in the current review was 16.9/28 (range 8-26), which equates to an average Quality Index of 60%. Overall, the level of evidence is best summarised as 'Conflicting' [62]. Several methodological issues can be identified within the selected studies. Regarding the *Quantity* studies, only one – Hohmann et al. (2011) – evaluated the effect of a physiotherapist-led rehabilitation program versus a fully unsupervised rehabilitation program. Across all other *Quantity* studies, both study groups received a degree of physiotherapist input during rehabilitation, with the quantity of that input differing between groups. It is possible the difference in the number of physiotherapy treatments between study groups was not sufficient to show any significant between-group differences [66]. The lack of outcome data for completely unsupervised subjects needs to be considered when evaluating the evidence that a home-based exercise program is equally effective as a clinic-based program [65].

Only 25% of studies in the current review reported, or attempted to measure, participant compliance with rehabilitation protocols. Increased compliance with rehabilitation following ACLR is associated with better patient outcomes [27, 80]. Compliance data is an important variable due to the dose-response relationship for effectiveness [21]. Measuring participant compliance with unsupervised rehabilitation may enable a more accurate comparison with patient outcomes following supervised rehabilitation.

Studies published more recently have shown a positive association between the quantity of post-ACLR rehabilitation and patient outcomes [43], and results of the current review support that finding. Three *Quantity* studies in the current review were published from 2019 onwards [48, 55, 58] – all reported a greater quantity of post-ACLR physiotherapy treatment was associated with improved patient outcomes. Six *Quantity* studies in the current review were published prior to 2010 [47, 49, 50, 57, 60, 61] – none reported an association between a greater amount of post-ACLR physiotherapy treatment and improved patient outcomes. There is little difference between the methodological quality of the newer verses the older studies, with the average Quality Index of the post-2019 studies being 57% (range 46-64%), and the average Quality Index of the pre-2010 studies being 59.5% (range 29-89%).

There was no clear relationship between methodological quality and the overall findings of the *Quantity* studies. Four *Quantity* studies scored greater than 70% on the Quality Index. One study reported the quantity of post-ACLR physiotherapy treatment had no effect on patient outcomes [47], with three reporting equivocal findings regarding the quantity of post-ACLR physiotherapy treatment and patient outcomes [49, 56, 57]. Three studies scored less than 50% on the Quality Index – two reported the quantity of post-ACLR physiotherapy treatment had no effect on patient outcomes [60, 61] and one reported a greater amount of post-ACLR physiotherapy treatment was associated with improved patient outcomes [55].

The timing of the final evaluation following a post-ACLR intervention could influence the overall findings of a study. If the final evaluation was performed when subjects are unlikely to have achieved optimum function, then the final evaluation may not fully capture the total effects of any intervention. Functional measures can improve for up to two years after ACLR [81]. Four *Quantity* studies reported results with a follow-up period of six months or less after ACLR – two reported the quantity of post-ACLR physiotherapy treatment had no effect on outcomes [47, 50], one reported less physiotherapy treatment resulted in better outcomes [49], and one reported more physiotherapy treatment resulted in better outcomes [58]. The remaining seven *Quantity* studies used follow-up periods of 12 months or greater (range 12-38 months) – two studies reported the quantity of post-ACLR physiotherapy treatment had no effect on outcomes [60, 61], two reported more physiotherapy treatment is associated with improved patient outcomes [48, 55], one reported less physiotherapy treatment is associated with improved outcomes [56], and two reported improved outcomes with more and less physiotherapy treatment [57, 59]. Overall, our results indicate the timing of the final subject evaluation following post-ACLR rehabilitation has little influence on the results of the *Quantity* studies.

With regards to *Duration* studies, two reported the duration of post-ACLR physiotherapy treatment had no effect on patient outcomes – both were rated as 'Moderate' quality, were published earlier, and had longer follow-up periods (24 months) [51, 54]. Two studies reported a longer duration of post-ACLR physiotherapy treatment resulted in better outcomes – both were rated 'Limited' quality, were published later, and had shorter follow-up periods (27-33 weeks) [52, 53]. Due to lack of published studies, it is not possible to conclude if study quality, date of publication, and the timing of the final subject evaluation influenced the findings of the *Duration* studies.

Limitations

This review is not without limitations. Of the 15 included studies, only two *Duration* studies were

conducted with the expressed aim of prospectively examining the effects of the quantity or duration of post-ACLR physiotherapy treatments on patient outcomes. None of the 11 *Quantity* studies specifically investigated the effects of the quantity of post-ACLR physiotherapy treatment on patient outcomes. Although the intended purpose of the majority of included studies did not completely align with the intended purpose of the review, it was considered appropriate to include them, as the dosage of post-ACLR physiotherapy treatment could be extracted from the articles. As such, the conclusions of this review regarding the effects of the quantity and duration of post-ACLR physiotherapy treatment are based on data that was not collected for the purpose for which it has been used. The literature search was completed up to March 2021, and therefore we cannot exclude the possibility further studies have been published since this date that may provide additional insights into the research question. As we excluded articles not published in English and did not search for unpublished studies, we may not have captured all the relevant literature. Considerable heterogeneity between the included studies precluded quantitative meta-analysis, while preventing any between-study comparison of interventions and outcomes.

Conclusions

The current review has not clearly established the quantity and duration of physiotherapy treatment following ACLR has a significant effect on patient outcomes. Similar outcomes are achieved irrespective of the dosage of physiotherapy treatment. This review adds to the findings of previous reviews that have shown no clear benefit of supervised rehabilitation over home-based or unsupervised rehabilitation following ACLR. Constant monitoring of post-ACLR rehabilitation by a physiotherapist does not appear necessary, although regular therapist review allows for ongoing patient assessment, education, and progression. High-quality RCTs investigating the optimal dosage of physiotherapy treatment following ACLR, or the level of supervision required during post-ACLR rehabilitation, to achieve acceptable patient outcomes are lacking.

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Appendix C.

Patient acceptance of knee symptoms and function after anterior cruciate ligament reconstruction improves with physiotherapy treatment. Published in New Zealand Journal of Physiotherapy.

RESEARCH REPORT

Patient Acceptance of Knee Symptoms and Function after Anterior Cruciate Ligament Reconstruction Improves with Physiotherapy Treatment

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ABSTRACT

Physiotherapy is considered an important component of rehabilitation following anterior cruciate ligament reconstruction (ACLR). The relationship between physiotherapy treatment and patient-reported outcomes following ACLR in New Zealand (NZ) is not clear. We used repeated measures logistic regression to examine the relationship between patient-reported outcome data from the NZ ACL Registry and physiotherapy treatment data from the Accident Compensation Corporation (ACC). Outcome measures utilised were the patient acceptable symptom state (PASS) on the Knee Injury Osteoarthritis and Outcome Score (KOOS⁴) and a normative score on the Marx Activity Rating Scale (MARS) within 24 months of ACLR. Data from 5,345 individuals were included in the final analysis, with a mean (*SD*) of 11.7 (10.5) (range 0–91) physiotherapy treatments received, over an average (*SD*) of 185 (153) (range 0–725) days, in the two years following ACLR. Physiotherapy treatment post-ACLR increased the likelihood of achieving a KOOS⁴ PASS score at 6 and 12 months, but not at 24 months, following surgery. Physiotherapy did not increase the likelihood of achieving a normative MARS score in the 24 months after ACLR. Multiple factors likely contribute to people who have had an ACLR in NZ receiving a low dosage of physiotherapy treatment following surgery. Physiotherapy treatment after ACLR may increase patient acceptance of any post-surgical symptoms and functional limitations, but the effect on post-operative activity levels is less clear.

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Key Words: ACL Reconstruction, Physiotherapy, Rehabilitation, Outcomes

INTRODUCTION

Functional rehabilitation following anterior cruciate ligament reconstruction (ACLR) is considered an effective intervention to increase the likelihood of a patient achieving their post-surgical goals (Lobb et al., 2012). In New Zealand (NZ), physiotherapists typically oversee rehabilitation following ACLR (Fausett et al., 2019). Therefore, the quantity and duration of post-operative physiotherapy treatment likely provides an accurate estimation of the dosage of rehabilitation received following ACLR in NZ. There remains no consensus on the optimal quantity and duration of post-ACLR physiotherapy treatment (Walker et al., 2020), with equivocal evidence as to whether the dosage of physiotherapy treatment following ACLR significantly influences patient-reported outcome scores, knee strength, functional ability, and graft re-rupture rates (Beynnon et al., 2011; Grant et al., 2005; Hohmann et al., 2011; Przybylak et al., 2019; Rhim et al., 2021; Vincent et al., 2017).

The dosage of treatment received by patients receiving community-based physiotherapy following ACLR can vary widely. Retrospective studies show patients post-ACLR receive between 15 and 50+ physiotherapy treatments following surgery (Burroughs et al., 2021; Christensen et al., 2017; Dempsey et al., 2019; Miller et al., 2017). The number of treatments physiotherapists report using following ACLR ranges from 20 to 60 but can exceed 100 (Dingenen et al., 2021; Ebert et al., 2019a; Korakakis et al., 2021). The reported duration of post-ACLR rehabilitation for community-based patients ranges between 127–175 days (Christensen et al., 2017; Dempsey et al., 2019; Miller et al., 2017), with the duration rarely exceeding 6 months (Dunphy & Gardner, 2020; Ebert et al., 2018; Edwards et al., 2018).

Outcomes following ACLR are typically evaluated with a combination of functional measures and patient-reported outcomes measures (PROMs) (Filbay & Grindem, 2019). There are over 50 PROMs related to the anterior cruciate ligament (ACL) deficient knee (Johnson & Smith, 2001). The Knee Injury Osteoarthritis and Outcome Score (KOOS) and the Marx Activity Rating Scale (MARS) are two PROMs consistently utilised in

ACL research and by ACL registries (Kanakamedala et al., 2016; Senorski, Svantesson, Engebretson, et al., 2019). As discrepancies can exist between post-operative PROM scores and patient satisfaction levels, the concept of a patient acceptable symptom state (PASS) may better facilitate interpretation of a PROM (Cristiani et al., 2020; Wright et al., 2015). The PASS is defined as the PROM score beyond which patients consider themselves well (Tubach et al., 2005). PASS thresholds have been developed for each subscale of the KOOS (Muller et al., 2016), and measurement of the PASS is a valuable complement to the KOOS in ACL injury (Svantesson et al., 2020). PASS thresholds, which are derived from a population with the condition of interest, differ from normative scores, which are derived from people who have never had the condition.

The Accident Compensation Corporation (ACC) of NZ is a government-funded no-fault insurance scheme, which funds treatment and rehabilitation costs for personal injuries caused by an accident, as defined by the ACC Act of 2001 (Todd, 2011). An injury claim is lodged on behalf of the patient by their treatment provider and, if accepted, treatment costs are funded under that specific claim (Bismark & Paterson, 2006). As ACL injuries in NZ are typically the result of an accident (Gianotti et al., 2009), treatment and rehabilitation costs for ACL injuries in NZ are usually met by ACC. ACC is the primary funder of private physiotherapy services in NZ (Reid & Larmer, 2007). Patients receiving treatment from private physiotherapists are typically charged a co-payment, as ACC funding does not usually cover the full cost of the treatment (New Zealand Government, 2007). ACC requires physiotherapy providers to collect visual analogue scale (VAS) pain scores and patient specific functional scale (PSFS) scores from patients; however, ACC does not collect this data from providers. Therefore, although ACC has visibility regarding the dosage of rehabilitation provided following ACLR, it has no knowledge of the specific outcome, or effectiveness, of that rehabilitation. ACC has also historically placed limits on the number of physiotherapy treatments it would fund following a musculoskeletal injury, with the maximum number of treatments following ACL injury being sixteen. Once the treatment number limit has been reached, the physiotherapist must apply to ACC for funding of additional treatments.

ACL registries provide a unique opportunity to understand and interpret factors affecting patient-reported outcomes after ACLR (Prentice et al., 2018). The NZ ACL Registry has been collecting PROM data for NZ ACLR patients since 2014, with almost 90% of ACLRs performed in 2020 enrolled by the registry (New Zealand ACL Registry, 2021). To date, it has not been possible to correlate these patient outcomes with the rehabilitation received, as the NZ ACL Registry does not collect data related to post-surgical physiotherapy treatment. Therefore, the purpose of this study was to explore the quantity and duration of physiotherapy treatment following primary, unilateral ACLR in NZ, and to determine the relationship between that dosage of physiotherapy treatment and patient-reported outcomes in the two years following surgery.

METHODS

Data sources

This retrospective study used outcome data from November 2014 to 1 December 2019 from the NZ ACL Registry. The data included pre-ACL injury MARS score, pre-ACLR KOOS/MARS scores, and post-ACLR KOOS/MARS scores at 6, 12, and 24 months. The data was forwarded to ACC's Analytics and Research department in a password-protected Microsoft Excel spreadsheet. As outcome data were collected independent of the physiotherapy provider, all individuals had the opportunity to complete PROMs at all data collection points, even if the individual was not engaged in physiotherapy treatment at the time of PROM data collection.

Using individual identifiers – National Health Index (NHI) number, and/or date of birth, and/or date of ACL injury – outcome data was matched to the ACC claim under which the ACLR was funded. Once individual outcome data and the ACC claim were matched, the following variables were extracted from the ACC claims management software system (Fineos) into a password-protected Microsoft Excel spreadsheet:

- Age at date of ACLR.
- Gender.
- Date of ACLR.
- Number of days between ACL injury and ACLR.
- Number of physiotherapy treatments in the 12 months prior to ACLR.
- Number of physiotherapy treatments between 0–6, 7–12, and 13–24 months post-ACLR.
- Date of first and last physiotherapy treatment after ACLR.
- Whether the individual had received vocational rehabilitation following ACLR.

Once extracted, patient data were de-identified and forwarded to the primary investigator for analysis. Individuals were excluded if patient-reported outcome data was either missing or unavailable from more than one post-ACLR time point. Unavailable data was defined as data yet to be collected, as that time point after ACLR had not yet been reached. Other exclusion criteria included ACLR revision, as subjective outcomes for this population are typically worse than for primary surgery (Lind et al., 2012; Wright et al., 2012), or non-ACC funded ACLR, as ACC would not hold physiotherapy treatment data for these individuals.

Outcome measures

The primary outcomes were the achievement of a KOOS[4] PASS score or a normative MARS score. The KOOS is composed of five subscales: pain, knee-related symptoms, activities of daily living (ADL), function in sport and recreation, and quality of life (Roos et al., 1998). Items on the KOOS are scored from 0 (no problem) to 4 (extreme problem) on a 5-point Likert scale. Scores from each subscale are transformed to a 0–100 scale, with 0 representing "extreme knee problems" and 100 representing "no knee problems". The KOOS[4] is an average of four subscales, where the ADL subscale is excluded to avoid a ceiling effect, as younger, more active patients rarely have difficulties with activities of daily living (Frobell et al., 2010). Excluding the ADL subscale mitigates the risk of a high score on the ADL subscale artificially inflating the KOOS[4] score.

The achievement of a KOOS[4] PASS score was based on individual KOOS subscale threshold values established by Muller et al. (2016), who asked ACLR patients: "Taking account of all the activity you have during your daily life, your level of pain, and also your activity limitations and participation restrictions, do you consider the current state of your knee satisfactory?" (p. 2821). Corresponding PASS values for the KOOS subscales were Pain > 88.9, Symptoms > 57.1, Sport and Recreation > 75.0, Quality of Life > 62.5, which equates to a KOOS[4] PASS score of 70.9. Individuals were not required to achieve a PASS score on each of the four subscales.

The MARS is a knee-specific questionnaire that evaluates activity level in people with various knee disorders (Marx et al., 2001). The MARS assesses the ability to perform four functional activities: running, cutting, decelerating, and pivoting. Participants record how often they perform these activities on a 0–4 scale, with 4 being most active. The maximum possible MARS score is 16. We used a MARS score of 11 for females and 12 for males as normative values (Cameron et al., 2015).

Statistical analysis

Initial descriptive analysis examined the distributions of the outcome and explanatory measures. The available confounding factors were identified as gender, age group, received vocational rehabilitation post-ACLR, and number of days between ACL injury. A repeated measures logistic regression with unstructured correlation was used to examine the association between dichotomous outcome measures and physiotherapy treatment, adjusting for the confounders and time varying effects.

RESULTS

Outcome data for 9,562 individuals was received from the NZ ACL registry (Figure 1). Outcome data was unable to be matched to an ACC claim for 4% of individuals due to a missing NHI number, date of birth, or date of ACL injury. Physiotherapy treatment data was not recorded for 7%. Two out of the possible three post-ACLR outcome data points were either missing or unavailable for 33%. Sufficient outcome data was available and able to be matched to the corresponding ACC claim, from which physiotherapy treatment data was able to be extracted, for 56% of individuals.

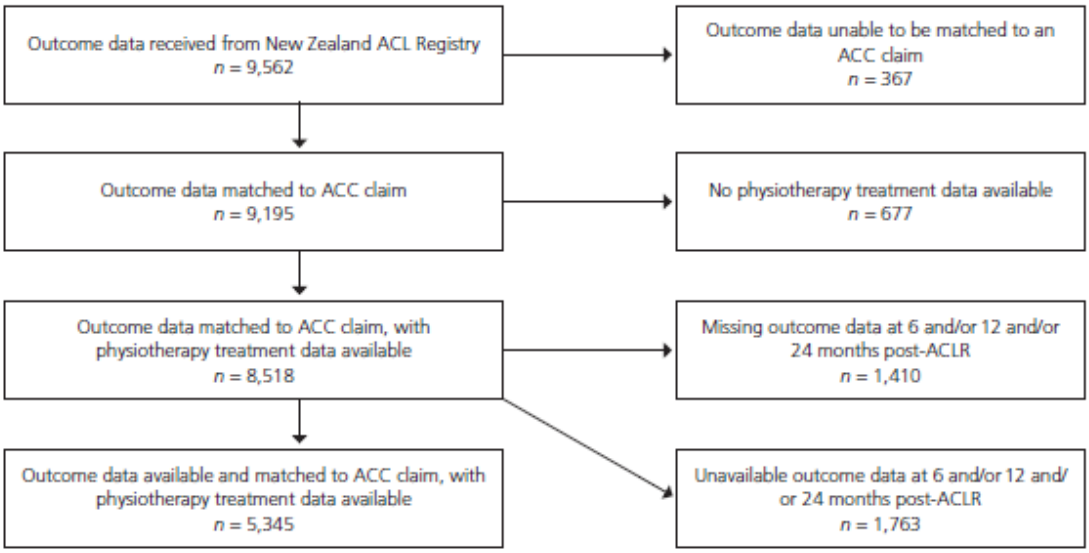
Descriptive analysis of the groups included and excluded from the final data set revealed the percentage of males differed across all groups, with males more likely to have missing physiotherapy treatment data and missing outcome data (Table 1). Individuals with missing outcome data were more likely to be younger at the time of ACLR but less likely to have received vocational rehabilitation. Those with missing physiotherapy treatment data had a longer delay to ACLR and were less likely to have received vocational rehabilitation.

Physiotherapy treatment following ACLR

The average (*SD*) number of physiotherapy treatments in the 12 months prior to ACLR was 5.5 (5.2) (range 0–39) (Figure 2). The average (with *SD* in parentheses) number of physiotherapy treatments 0–6 months post-ACLR was 9.2 (7.2) (range 0–67), 7–12 months post-ACLR was 1.9 (3.7) (range 0–54), and 13–24 months post-ACLR was 0.6 (2.4) (range 0–35). The average (*SD*)

Figure 1

Flow Chart Showing Derivation of Final Data Set



Note. ACC = Accident Compensation Corporation; ACL = anterior cruciate ligament; ACLR = anterior cruciate ligament reconstruction.

Table 1

Descriptive Covariate Values for Individuals Included and Excluded From the Final Data Set

Variable		Outcome data received from NZ ACL Registry (*n* = 9,562)	Outcome data unmatched to ACC claim (*n* = 367)	Physiotherapy treatment data missing (*n* = 677)	Outcome data missing (*n* = 1,410)	Outcome data unavailable (*n* = 1,763)	Physiotherapy treatment data and outcome data available and matched (*n* = 5,345)	*p* [b]
					% [a]			
Gender	Male	57.6	63.2	69.4	70.7	54.3	53.3	< 0.0001
Age at ACLR, *M* (*SD*), range, years		27.8 (11.1), 8–70	28.8 (10.5), 11–64	29.4 (10.9), 9–70	25.6 (9.3), 10–63	28.7 (10.8), 10–69	29.4 (11.2), 8–69	
Age at ACLR, years	8–20	29	20	23	36	26	24	< 0.0001
	21–30	38	47	38	40	38	37	
	31–40	18	18	22	15	20	20	
	41–69	15	15	17	9	16	19	
Days from ACL injury to ACLR, *M* (*SD*), range, years		289 (723), 12–16,025	290 (928), 14–15,418	422 (975), 17–8,801	252 (637), 16–14,406	234 (605), 12–16,025	287 (708), 14–12,163	
Days from ACL injury to ACLR	14–79	26	29	22	27	26	25	< 0.0001
	80–126	24	20	24	23	24	25	
	127–230	25	23	23	25	29	25	
	231+	25	23	31	25	21	25	
	Missing	–	5	–	–	–	–	
Had vocational rehabilitation	Yes	33.4	–	22.2	40.1	32.3	35.6	< 0.0001
	No	66.6	–	77.8	59.9	67.7	64.4	
Pre-injury MARS score, *M* (*SD*)		11.4 (4.9)	11.4 (5.0)	10.4 (5.3)	11.2 (5.2)	11.6 (4.8)	11.7 (4.8)	

Note. ACC = Accident Compensation Corporation; ACL = anterior cruciate ligament; ACLR = anterior cruciate ligament reconstruction; NZ = New Zealand.

[a] Except where indicated. [b] Chi-square test.

total number of physiotherapy treatments in the 24 months post-ACLR was 11.7 (10.5) (range 0–91). The percentage of individuals who did not receive physiotherapy treatment pre-ACLR, and 0–6, 7–12, and 13–24 months post-ACLR, was 22%, 12%, 57%, and 88% respectively (Figure 2).

The duration of post-ACLR physiotherapy treatment was less than 6 months for 57% of individuals, while post-ACLR physiotherapy treatment lasted longer than 9 months for 25% of individuals (Figure 3). The average (*SD*) number of days from the first post-ACLR physiotherapy treatment to the last treatment was 185 (153) days (range 0–725).

Patient-reported outcomes following ACLR

KOOS[4]

The likelihood of an individual achieving a KOOS[4] PASS score following ACLR increased significantly over time ($p < 0.0001$) (Table 2). The percentage of individuals achieving a KOOS[4] PASS score pre-ACLR, and at 6, 12, and 24 months post-ACLR, was 17%, 53%, 70%, and 75% respectively (Figure 4).

MARS

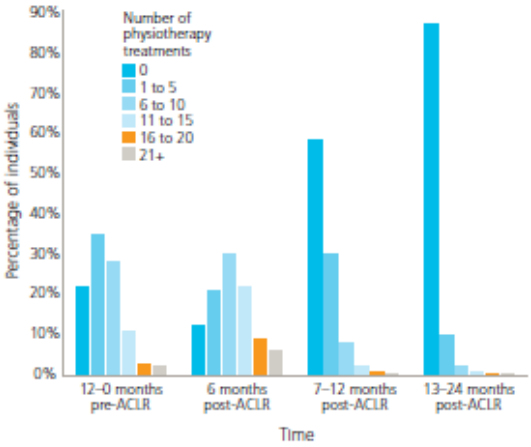
The likelihood of an individual achieving a normative MARS score following ACLR increased significantly over time ($p < 0.0001$) (Table 3). The percentage of individuals achieving a normative MARS score pre-ACLR, and at 6, 12, and 24 months post-ACLR, was 5%, 11%, 23%, and 28% respectively (Figure 5).

Relationship between physiotherapy treatment and patient-reported outcomes – univariate analysis

Post-ACLR physiotherapy treatment was initially grouped into 0, 1, 2–4, and 5+ treatments, as these treatment numbers approximated quartile divisions within the complete data set. Initial analyses showed a statistically significant increase in the likelihood of achieving a KOOS[4] PASS score for one physiotherapy treatment over no physiotherapy treatments 0–6 and 7–12 months post-ACLR ($p = 0.04$), with lesser non-significant increases for 2–4 and 5+ treatments (Table 4). There was no effect of different quantities of post-ACLR physiotherapy

Figure 2

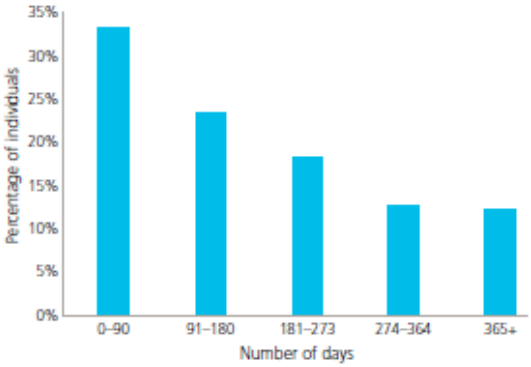
Average Number of Physiotherapy Treatments Per Individual



Note. ACLR = anterior cruciate ligament reconstruction.

Figure 3

Number of Days Between First and Last Physiotherapy Treatment Following ACLR



Note. ACLR = anterior cruciate ligament repair.

Table 2

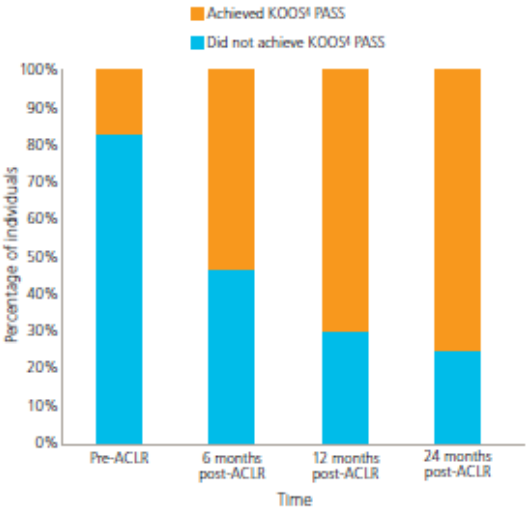
Unadjusted Odds Ratios For the Likelihood of Achieving a KOOS⁴ PASS Score Following ACLR

Time since ACLR	*OR*	95% CI		*p*
		LL	*UL*	
Pre-ACLR	1.00	–	–	
6 months	5.34	4.92	5.79	
12 months	10.87	9.96	11.86	
24 months	13.99	12.64	15.49	< 0.0001

Note. ACLR = anterior cruciate ligament reconstruction; CI = confidence interval; KOOS⁴ PASS = Knee Injury Osteoarthritis and Outcome Score, patient acceptable symptom state; *LL* = lower limit; *UL* = upper limit.

Figure 4

Individuals Achieving a KOOS⁴ PASS Score Over Time



Note . ACLR = anterior cruciate ligament reconstruction; KOOS⁴ PASS = Knee Injury Osteoarthritis and Outcome Score, patient acceptable symptom state.

treatment on the likelihood of achieving a normative MARS score. Therefore, the physiotherapy treatment groups were collapsed into whether or not physiotherapy treatment was present.

KOOS⁴

The percentage of individuals who achieved a KOOS⁴ PASS score at each time point, based on whether they received physiotherapy treatment, is shown in Figure 6. Overall, there was a significant association between receiving physiotherapy treatment and the likelihood of achieving a KOOS⁴ PASS score following ACLR ($p = 0.0024$), with physiotherapy treatment at 7–12 months associated with an increased likelihood of achieving a KOOS⁴ PASS score at 12 months post-ACLR (Table 5).

MARS

The percentage of individuals who achieved a normative MARS score at each time point, based on whether they received physiotherapy treatment, is shown in Figure 7. Overall, there was a significant association between receiving physiotherapy treatment and the likelihood of achieving a normative MARS score following ACLR ($p = 0.0003$), with physiotherapy treatment between 7–12 and 13–24 months associated with an

Table 3

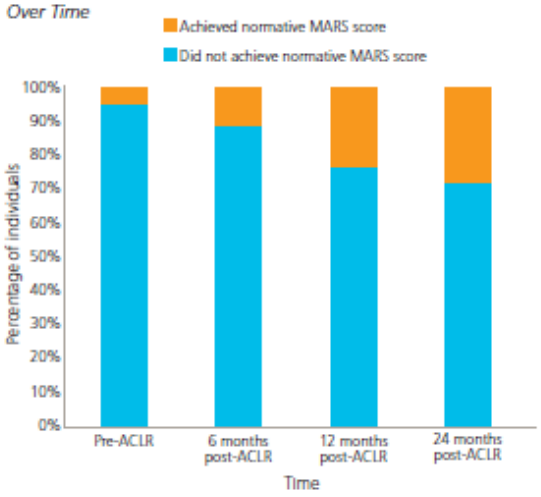
Unadjusted Odds Ratios for the Likelihood of Achieving a Normative Marx Activity Rating Scale Score Following ACLR

Time since ACLR	*OR*	95% CI		*p*
		LL	*UL*	
Pre-ACLR	1.00	–	–	
6 months	2.20	1.90	2.55	
12 months	5.86	5.10	6.73	
24 months	7.53	6.52	8.70	< 0.0001

Note. ACLR = anterior cruciate ligament reconstruction; CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

Figure 5

Individuals Achieving a Normative Marx Activity Rating Scale Over Time



Note. ACLR = anterior cruciate ligament reconstruction; MARS = Marx Activity Rating Scale.

increased likelihood of achieving a normative MARS score at 12 and 24 months after surgery respectively (Table 6).

Relationship between physiotherapy treatment and patient-reported outcomes – multivariate analysis

When adjusted for confounding variables, there was a significant relationship between physiotherapy treatment and likelihood of achieving a KOOS[4] PASS score following ACLR ($p = 0.0035$) (Table 7). Physiotherapy treatment between 0–6 months and 7–12 months increased the likelihood of achieving a KOOS[4] PASS score at 6 and 12 months respectively. However, when adjusted for confounders, the relationship between physiotherapy treatment and the likelihood of achieving a normative MARS score following ACLR did not reach significance ($p = 0.15$). Physiotherapy treatment during all post-operative time periods was not associated with an increased likelihood of achieving a normative MARS score at any post-operative time point. Unadjusted and adjusted odds ratios for KOOS[4] PASS scores and normative MARS scores for all variables are presented in Appendices A and B.

Table 4

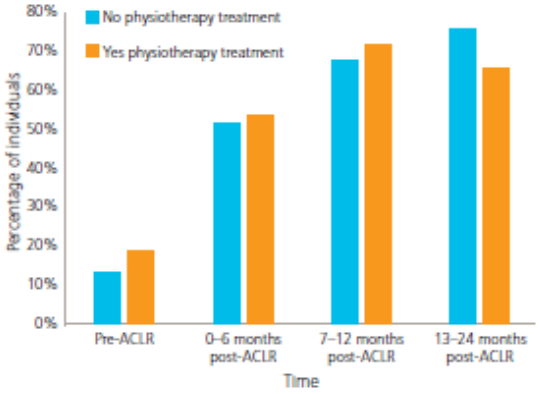
Unadjusted Odds Ratios for Physiotherapy Treatment and the Likelihood of Achieving a KOOS[4] PASS Score Following ACLR

Time since ACLR	Number of physiotherapy treatments	*OR*	95% CI	
			LL	*UL*
0–6 months	0	1.00	–	–
	1	1.45	1.01	2.09
	2–4	1.20	0.96	1.49
	5+	1.18	0.99	1.39
7–12 months	0	1.00	–	–
	1	1.31	1.08	1.59
	2–4	1.12	0.96	1.31
	5+	1.17	0.99	1.39
13–24 months	0	1.00	–	–
	1	0.90	0.62	1.33
	2–4	0.88	0.60	1.27
	5+	0.77	0.50	1.17

Note. ACLR = anterior cruciate ligament reconstruction; CI = confidence interval; KOOS[4] PASS = Knee Injury Osteoarthritis and Outcome Score, patient acceptable symptom state; *LL* = lower limit; *UL* = upper limit.

Figure 6

Individuals Achieving a KOOS[4] PASS Score and If They Received Physiotherapy Treatment



Note . ACLR = anterior cruciate ligament reconstruction; KOOS[4] PASS = Knee Injury Osteoarthritis and Outcome Score, patient acceptable symptom state.

Table 5

Unadjusted Odds Ratios for Individuals Receiving Physiotherapy Treatment and the Likelihood of Achieving a KOOS⁴ PASS Score Following ACLR

Time since ACLR	Physiotherapy treatment	*OR*	95% CI	
			LL	*UL*
0–6 months	No	1.00		
	Yes	1.12	0.95	1.31
7–12 months	No	1.00		
	Yes	1.21	1.08	1.36
13–24 months	No	1.00		
	Yes	0.86	0.68	1.09

Note. ACLR = anterior cruciate ligament reconstruction; CI = confidence interval; KOOS⁴ PASS = Knee Injury Osteoarthritis and Outcome Score, patient acceptable symptom state; *LL* = lower limit; *UL* = upper limit.

Figure 7

Individuals Achieving a Normative Marx Activity Rating Scale and If They Received Physiotherapy Treatment

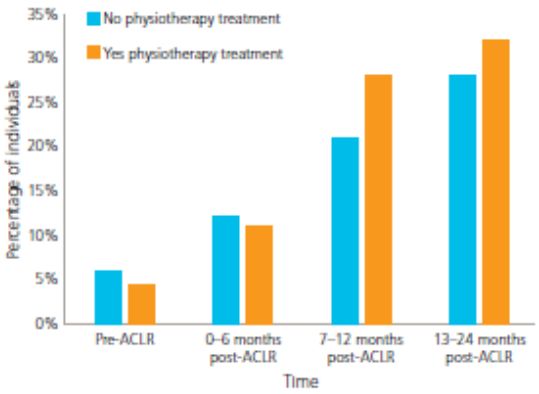


Table 6

Unadjusted Odds Ratios for Individuals Receiving Physiotherapy Treatment and the Likelihood of Achieving a Normative Marx Activity Rating Scale Score Following ACLR

Time since ACLR	Physiotherapy treatment	*OR*	95% CI	
			LL	*UL*
0–6 months	No	1.00		
	Yes	0.95	0.71	1.27
7–12 months	No	1.00		
	Yes	1.27	1.12	1.46
13–24 months	No	1.00		
	Yes	1.40	1.12	1.75

Note. ACLR = anterior cruciate ligament reconstruction; CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

Table 7

Adjusted Odds Ratios for Receiving Physiotherapy Treatment and the Likelihood of Achieving a KOOS⁴ PASS Score and a Normative Marx Activity Rating Scale Score Following ACLR

Variable	Time since ACLR	Physiotherapy treatment	*OR*	95% CI	
				LL	*UL*
KOOS⁴	0–6 months	No	1.00		
		Yes	1.19	1.01	1.41
	7–12 months	No	1.00		
		Yes	1.18	1.05	1.33
	13–24 months	No	1.00		
		Yes	0.84	0.67	1.07
MARS	0–6 months	No	1.00		
		Yes	0.91	0.68	1.23
	7–12 months	No	1.00		
		Yes	1.13	0.97	1.31
	13–24 months	No	1.00		
		Yes	1.24	0.97	1.58

Note. ACLR = anterior cruciate ligament reconstruction; CI = confidence interval; KOOS⁴ PASS = Knee Injury Osteoarthritis and Outcome Score, patient acceptable symptom state; LL = lower limit; MARS = Marx Activity Rating Scale; UL = upper limit.

DISCUSSION

The aim of this study was to explore the dosage of physiotherapy treatment following ACLR in NZ, and to determine the relationship between the quantity of physiotherapy treatment and patient-reported outcomes in the 2 years following surgery. Our results showed physiotherapy treatment in the first 12 months following ACLR was associated with an increased likelihood of achieving a KOOS⁴ PASS score. Physiotherapy treatment in the 24 months following ACLR was not associated with an increased likelihood of achieving a normative MARS score. A greater number of physiotherapy treatments following ACLR was not associated with an increased likelihood of achieving a KOOS⁴ PASS score or a normative MARS score in the 24 months following surgery. Overall, individuals received a low dosage of physiotherapy treatment following ACLR in NZ.

This is the first study to show a relationship between physiotherapy treatment and the achievement of a KOOS⁴ PASS score following ACLR. Other factors associated with achieving a KOOS⁴ PASS score after an ACLR include the absence of a concomitant medial collateral ligament injury and receiving a hamstring tendon graft (Senorski et al., 2018). Age, gender, quadriceps symmetry, absence of concomitant cartilage and meniscal injuries, and hop test performance are also associated with achieving PASS scores on subscales of the KOOS following ACLR (Cristiani et al., 2020; Senorski et al., 2018). Of these factors, only quadriceps symmetry and hop test performance

can be modified by rehabilitation, i.e., physiotherapy treatment. Physiotherapy treatment following ACLR has been shown to improve quadriceps and hamstring strength (Dempsey et al., 2019; Rhim et al., 2021; Walston & Barillas, 2021) and lower limb function (Ebert et al., 2018; Lim et al., 2019). Therefore, physiotherapy treatment potentially contributes to the positive correlation between functional performance and KOOS scores following ACLR (Reinke et al., 2011).

Physiotherapy treatment between 13 and 24 months after ACLR was associated with decreased likelihood of achieving a KOOS⁴ PASS score, both in the univariate and multivariate analyses, although results did not reach statistical significance. A lower percentage of individuals who received physiotherapy treatment from 13 to 24 months achieved a KOOS⁴ PASS score at 24 months. Physiotherapy treatment after ACLR is recommended to last up to 12 months (van Melick et al., 2016). Therefore, if physiotherapy treatment is required after 12 months, there have potentially been post-operative complications (Eckenrode et al., 2017; Lord et al., 2020), which necessitated prolonged physiotherapy treatment and likely contributed to a worse outcome.

In the univariate analysis, physiotherapy treatment between 7–12 and 13–24 months after ACLR was associated with a significantly increased likelihood of achieving a normative MARS score. When considered with other confounding variables, there was a trend for physiotherapy treatment between 7 and 24 months to be associated with an increased likelihood of achieving a normative MARS score, but significance was not reached. The relationship between physiotherapy treatment and MARS scores following ACLR has not been previously reported. However, physiotherapy treatment following ACLR has been associated with higher scores on the Tegner Activity Scale (Przybylak et al., 2019; Revenäs et al., 2009), which, as with the MARS, quantifies activity level following knee injury (Collins et al., 2011).

Not unexpectedly, the percentage of individuals achieving KOOS⁴ PASS scores and normative MARS scores improved over time following ACLR. Our results show 75% of patients post-ACLR perceive their symptoms as acceptable at 2 years post-surgery, which is consistent with previous research (Ingelsrud et al., 2015). Only 28% of individuals had achieved a normative MARS score at 2 years post-ACLR. Although the percentage achieving a normative MARS score increased over time, the average MARS score at 24 months post-ACLR was only 61% of the average pre-injury score, suggesting a low rate of return to pre-injury activity levels after 24 months. Previous research, using MARS data from the same population, reported only 11.1% and 15.5% of patients in NZ have returned to pre-injury activity levels at 12 and 24 months respectively following ACLR (Rahardja et al., 2021). Our study therefore adds to the body of work showing a significant number of people do not achieve pre-injury activity levels 2 years after ACLR (Antosh et al., 2018; Cox et al., 2014; Dunn et al., 2010).

Preliminary analysis of the KOOS⁴ data used a normative score as the dependent variable in the statistical model. However, the number of individuals achieving a normative KOOS⁴ score at each time point was so low the statistical model failed. Previous research has shown most people do not achieve normative KOOS scores within 2 years of ACLR (Herrington, 2013). As a significant number of patients achieve a PASS score on four out of the five KOOS subscales at 12 months after ACLR (Senorski et al., 2018), a KOOS⁴ PASS score was therefore selected as a dependent variable. A normative MARS score was selected as a dependent variable in the current study, as, to date, no PASS scores have been published for the MARS.

Normative values need to be considered in the context of the population from which they were derived. The normative MARS values used in the current study were derived from a cohort of United States military academy recruits, with an average (*SD*) age of 18.8 (0.9) years for males and 18.7 (0.7) years for females (Cameron et al., 2015); the only published normative MARS scores to date. In the current study, average age of individuals at time of ACLR was 29.5 years for males and 29.3 years for females, with an age range from 8 to 69 years. Only 11% of individuals were aged 17–19 years. Younger people have higher participation rates in ACL-dependent activities (Eime et al., 2016), which would be reflected in higher MARS scores. Following ACLR, MARS scores decline with increasing age (Randsborg et al., 2022; Spindler et al., 2018). Therefore, the average age of individuals in the current study likely contributed to the low percentage achieving a normative MARS score following ACLR.

Patient-reported outcome measures are not routinely utilised by physiotherapists in clinical practice (Jette et al., 2009). Although there is no data on the general utilisation of PROMs by NZ physiotherapists, only 52% of NZ physiotherapists report using PROMs when considering a return to sport after ACLR (Fausett et al., 2022). Patient-reported outcome data following ACLR in NZ is collected by an ACL Registry. This is an ACC-funded organisation set up by the Knee and Sports Society, which is a branch of the NZ Orthopaedic Association (New Zealand ACL Registry, 2021). The NZ ACL Registry has no links to physiotherapy providers in NZ. Therefore, the collection of PROM data following ACLR is independent of the providers delivering the post-surgical rehabilitation, arguably independence that eliminates any bias the physiotherapist may introduce by their collection of the PROM data. However, collection of the PROM data is not correlated specifically to a particular stage of rehabilitation and the physiotherapist has no visibility of the PROM scores. PROM data is collected by the NZ ACL Registry at 6, 12, and 24 month intervals following ACLR. More frequent collection of PROM data by the physiotherapist may offer greater insights into the patient's rehabilitation progress, with the rehabilitation plan able to be adjusted or modified if required.

Our results show individuals in NZ receive a low dosage of physiotherapy treatment following ACLR, with less than 12 treatments over 185 days. Previous retrospective studies have shown community-based patients can receive 15–58 treatments over 127–175 days following ACLR (Christensen et al., 2017; Dempsey et al., 2019; Miller et al., 2017). This large range reflects the lack of a consensus regarding an optimal number of physiotherapy treatments following ACLR (Walker et al., 2020). While no optimal number of physiotherapy treatment sessions exists that can be applied to all patients, the number of treatments required by each patient will be a product of

their post-operative goals and individual progress through their rehabilitation programme. Following ACLR, a fortnightly review with the treating physiotherapist is suggested as the minimum requirement (Filbay & Grindem, 2019), and if rehabilitation lasts the recommended 9–12 months (van Melick et al., 2016), then the minimum number of post-ACLR physiotherapy treatments would be 18–24. Ultimately, the optimal number of physiotherapy treatments for each individual will be the number of treatments they require to achieve their post-operative goals.

The temporal utilisation of a limited number of physiotherapy treatments following ACLR could also influence the duration of rehabilitation. Individuals in the current study received 79% of post-ACLR physiotherapy treatments within 6 months of surgery – a finding consistent with a recent database analysis of over 11,000 ACLR patients that reported 90% of post-ACLR physiotherapy treatments were received within 4 months of surgery (Burroughs et al., 2021). If the majority of allocated treatments are utilised within a short timeframe after surgery, then the premature cessation of rehabilitation may be decided by the allocated number of treatments rather than the achievement of patient goals.

For almost 60% of individuals in the current study, post-ACLR physiotherapy treatment lasted less than 6 months, with physiotherapy lasting at least 9 months for only a quarter of individuals. Although time-based rehabilitation following ACLR has now been succeeded by criterion-based rehabilitation (Meredith et al., 2020), time from surgery is still the most considered factor when assessing a return to sport (Burgi et al., 2019). Few patients achieve recommended criteria to resume pre-injury activities within 9 months of ACLR surgery (Herbst et al., 2015; Toole et al., 2017; Welling et al., 2018), and a return to pre-injury activities before 9 months significantly increases the risk of re-injury (Beischer et al., 2020; Bodkin et al., 2022; Grindem et al., 2016). The risk of re-injury following ACLR is also highest in the first 6–12 months of a return to pre-injury activities (Paterno et al., 2012; Webster & Feller, 2016). Therefore, physiotherapist treatment and oversight of rehabilitation 7–12 months after ACLR may help reduce the risk of ACL re-injury at a time when most patients are considering returning to pre-injury activities.

The final phase of ACLR rehabilitation typically involves a resumption of functional activities, sport-specific training, and a graduated return to pre-injury sports (Buckthorpe, 2019), with most patients expecting a return to pre-injury activities 6–12 months after surgery (Armento et al., 2020; Feucht et al., 2016). Individuals in the current study received on average less than two physiotherapy treatments 7–12 months after ACLR, with 58% receiving no physiotherapy treatment during this time. Therefore, our results suggest NZ ACLR patients are undertaking end-stage rehabilitation without adequate professional oversight (Ebert et al., 2019a; Filbay & Grindem, 2019). Low numbers of physiotherapy treatments at 7–12 months could reflect increased self-management (Ebert et al., 2019a), decreased patient compliance (Risberg et al., 2016), a lack of physiotherapist skill and knowledge to manage a patient through the return to sport phase following ACLR (Walker et al., 2020), or the use of non-physiotherapy providers for rehabilitation guidance (Walker et al., 2021).

Multiple factors likely contribute to patients receiving a low dosage of physiotherapy treatment following ACLR, including low motivation to complete rehabilitation (Thorstensson et al., 2009), a lack of patient education regarding post-ACLR rehabilitation (Cailliez et al., 2012), or a lack of surgeon endorsement of rehabilitation (Ebert et al., 2019b). Patients also report frustration and disappointment with a physiotherapist's ability to manage late-stage ACLR rehabilitation (Walker et al., 2022), which could lead to patients prematurely disengaging in physiotherapy, resulting in a low number of treatments.

From a NZ-specific perspective, the provider co-payment, which can be up to $50 per treatment, for a private physiotherapy treatment, likely represents a significant barrier to a patient receiving the recommended dosage of physiotherapy following ACLR. The limits placed on the number of physiotherapy treatments for an ACL injury by ACC have also potentially contributed to low numbers of treatments being used in the current study. The physiotherapist has to submit a request to ACC for funding of additional treatments by providing their clinical records and a completed ACC32 form, which includes details regarding the patient's current condition, how the current condition is linked to the covered injury, and a plan for the additional treatments. The request is then clinically assessed by ACC, with a subsequent decision issued to either approve or decline the request. This prior approval process represents a barrier to receiving additional physiotherapy treatments, as a decision to decline additional funding results in the patient being liable for the full cost of any further physiotherapy treatment, further compounding any financial burden on the patient. Other potential factors preventing engagement in physiotherapy following ACLR include patient-specific barriers (health literacy/understanding of the condition, cultural beliefs, socioeconomic status), provider-specific barriers (patient interactions), and healthcare system barriers (waiting times, location of services, involvement of multiple providers) (Fausett et al., 2019).

A strength of the current study is the large number of individuals, which provides a level of statistical robustness. However, large cohorts increase the likelihood of significant results, even if those results may not be clinically relevant (Senorski, Svantesson, Baldari, et al., 2019). We used deterministic linkage to match two large, separate data sets, which can produce false negative links due to missing data and erroneous entries (Zhu et al., 2015). The retrospective design, while allowing a large cohort, prevents any causal links being established. ACC clients with an ACL injury may have more than one knee claim related to their ACL injury. Therefore, we cannot rule out the possibility of individuals receiving post-ACLR physiotherapy treatment under a knee claim that the ACLR was not funded under. However, this scenario is unlikely to apply to a large number of individuals, as ACC processes are designed to ensure all entitlements are funded under the correct claim. By choosing to use PROM data from the NZ ACL Registry, there was no control over the outcome measures used, and other PROMs may be more appropriate measures to assess patient outcomes within 2 years of ACLR. The International Knee Documentation Committee form is a more useful tool to evaluate patients in the first year after ACLR (van Meer et al., 2013) and the Tegner

activity scale (TAS) is recommended when assessing activity levels in ACLR patients, particularly in conjunction with the International Knee Documentation Committee (Wera et al., 2014).

CONCLUSION

Physiotherapy treatment improves subjective patient-reported outcomes following ACLR, although the effect of physiotherapy treatment on activity levels is less certain. The majority of individuals report acceptable symptoms and function at 2 years following ACLR, which is in contradiction to a low rate of return to pre-injury activity levels. Individuals undergoing ACLR in NZ receive a low dosage of physiotherapy treatment following surgery. The optimal number of physiotherapy treatments following ACLR remains unclear and is likely dependent on multiple factors. A well-controlled prognostic study examining the effects of various quantities of physiotherapy treatment on outcomes following ACLR is warranted. However, ethical issues would likely render the undertaking of such a study challenging. Future prospective research on outcomes following ACLR should consider the appropriateness of the outcome measures used and how the demographics of the cohort might influence any findings.

KEY POINTS

1. In the first 12 months following ACLR, physiotherapy treatment increases the likelihood of an individual accepting any ongoing symptoms or functional limitations; however, in the 24 months following ACLR, the effect of physiotherapy on activity levels is less clear.
2. The dosage of physiotherapy treatment received by NZ patients following ACLR is less than previous research suggests is required.
3. Multiple factors potentially influence the dosage of post-ACLR physiotherapy treatment in NZ, including financial barriers and health system requirements.
4. Regular assessment of the patient's status during ACLR rehabilitation, using both functional and patient-reported outcomes, will likely have multiple benefits, including providing an objective basis for the progression and modification of rehabilitation, and increasing and maintaining patient motivation.

DISCLOSURES

No funding was obtained for this research. At the time of this study, WF was employed by ACC as a clinical advisor, but this research was not undertaken in his capacity as an ACC employee. Although ACC provided the physiotherapy treatment data for analysis, ACC did not commission this research and was not involved in the planning and conducting of this research. ACC was made aware of the study prior to its commencement and was fully supportive of the research. All other authors report no conflict of interest.

PERMISSIONS

Ethical approval for this research was granted by the Auckland University of Technology Ethics Committee (reference number 19/293).

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CONTRIBUTIONS OF AUTHORS

Conceptualisation, design, and methodology, WF, DR, and PL; Formal analysis, NG and WF; Writing – original draft preparation, WF; Writing – review & editing, WF, DR and PL.

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Appendix D.

Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport following anterior cruciate ligament reconstruction: A survey. Published in Physical Therapy in Sport.

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Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport following anterior cruciate ligament reconstruction: A survey☆

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ABSTRACT

Objective: To investigate the clinical beliefs and practices of New Zealand physiotherapists regarding pre- and post-surgical rehabilitation and return to sport (RTS) criteria following anterior cruciate ligament reconstruction (ACLR).
Design: Online cross-sectional survey.
Methods: A survey was adapted from a previously published survey and disseminated to New Zealand physiotherapists who were considered more likely to be involved in post-ACLR rehabilitation.
Results: The number of completed surveys was 318. Most physiotherapists (85%) preferred to first consult patients within 14 days of ACLR. In the first six weeks following ACLR, 89% of physiotherapists see patients at least once per week. Between 3- and 6-months post-ACLR, 76% of physiotherapists see patients at least once a fortnight. Pre-operative rehabilitation and post-operative rehabilitation exceeding six months are considered essential or important to patient outcomes by over 95% of physiotherapists. While 63% of physiotherapists support RTS 9–12 months after ACLR, 11% permit RTS within 6–9 months of surgery. Common RTS considerations include functional capacity, movement quality during functional tasks, time from ACLR, and knee strength.
Conclusion: The survey revealed variability in the beliefs and practices of NZ physiotherapists regarding post-ACLR rehabilitation, and these beliefs and practices are at times inconsistent with best practice recommendations.

1. Introduction

Injury to the anterior cruciate ligament (ACL) of the knee typically occurs during sporting activities involving cutting, landing, and pivoting movements (Renström, 2013). Management of an ACL injury usually follows one of two pathways: 1) post-injury rehabilitation, followed by early surgical ACL reconstruction (ACLR) and post-surgical rehabilitation, or 2) post-injury rehabilitation, with the option of delayed ACLR if clinically indicated (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005). The goals of ACLR are to facilitate a safe and sustainable return to pre-injury activities and prevent secondary knee changes such as osteoarthritis, although recent research does not support these outcomes for a significant number of patients (Ardern, Taylor, Feller, & Webster, 2014; Harris et al., 2014). Despite no clear benefit of surgical over conservative management (Frobell et al., 2013; Wellsandt, Failla, Axe, & Snyder-Mackler, 2018), annual rates of ACLR in certain populations have increased by up to 40% in recent years (Abram, Price, Judge, & Beard, 2019; Herzog et al., 2018; Zbrojkiewicz, Vertullo, & Grayson, 2018).

Independent of the treatment pathway chosen following ACL injury, rehabilitation is a critical factor that can influence short- and long-term patient outcomes (van Melick et al., 2016). Rehabilitation for ACLR includes pre-operative rehabilitation, followed by criterion-based post-operative rehabilitation, and a graduated return to pre-injury activities (Grindem, Wellsandt, Failla, Snyder-Mackler, & Risberg, 2018). Pre-ACLR rehabilitation aims to eliminate any knee joint effusion, restore range of motion, and improve quadriceps strength (Filbay & Grindem, 2019; van Melick et al.,

☆ All subjects gave their informed consent to participate in this research.
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2016). The goals of post-ACLR rehabilitation are to restore neuromuscular function and modify any pre-injury risk factors that may increase the risk of subsequent ACL injury (Adams, Logerstedt, Hunter-Giordano, Axe, & Snyder-Mackler, 2012). While the effectiveness of rehabilitation following ACLR is well accepted (Lobb, Tumilty, & Claydon, 2012), there remains little consensus as to the optimal components of the rehabilitation program (Meredith et al., 2020). While clinical practice guidelines for post-ACL rehabilitation do exist, their usefulness in clinical practice may be limited due to low external validity (Andrade, Pereira, van Cingel, Staal, & Espregueira-Mendes, 2019).

The annual incidence of ACLR in New Zealand (NZ) has increased by 58% since 2005 (Sutherland, Clatworthy, Fulcher, Chang, & Young, 2019), and the annual cost of ACLR surgeries in NZ exceeds $25 million dollars (ACC, 2018a). Physiotherapists are key health professionals who manage pre- and post-ACLR rehabilitation (Filbay & Grindem, 2019); particularly so in the NZ context, where private practice-based physiotherapists oversee the significant majority of pre- and post-ACLR rehabilitation (Fausett, Wilkins, Reid, Larmer, & Potts, 2019). However, due to an underutilisation of physiotherapy services following surgery, patients undergoing ACLR in NZ may not be receiving an appropriate dosage of rehabilitation (Fausett et al., 2019).

There is considerable variability amongst therapists in beliefs and clinical practices regarding ACLR rehabilitation, including activity and exercise progression, knee strength testing, return to sport (RTS) timeframes, and frequency of treatment (Dingenen et al., 2021; Ebert et al., 2018; Greenberg, Greenberg, Albaugh, Storey, & Ganley, 2018). Although physiotherapists are the main providers of post-ACLR rehabilitation in NZ (ACC, 2018b), the beliefs and practices of NZ physiotherapists regarding rehabilitation following ACLR are currently unknown. Therefore, the aim of the current study was to investigate practice beliefs of NZ physiotherapists regarding pre- and post-surgical rehabilitation and RTS criteria following ACLR.

2. Methods

An online survey consisting of 14 questions was utilised to survey NZ physiotherapists. The survey was adapted from a previously published survey of Australian therapists involved in ACLR rehabilitation (Ebert et al., 2018), with permission to replicate the survey granted by the lead author. The survey questions and possible responses are shown in Table 1. There were two minor changes to the original survey. Question three regarding which state/territory the provider practiced in was removed, as this was not applicable to the NZ population. In the original survey, participants could select as many options as applicable for questions 14 and 15. For technical reasons, participants could only select one option for those questions in the current survey (questions 13 and 14 in the current study). All other questions in the current survey were duplicated from the original study.

The survey was available for completion via an online platform (SurveyMonkey) between April 23rd 2020 and June 31st 2020. The survey was anonymous, which was clearly stated in the information section, with no personal participant data collected. Participants were required to self-identify as NZ registered physiotherapists with an up-to-date annual practicing certificate who were currently treating, or had previously treated, a patient who had undergone ACLR. If a participant did not self-identify with the above criteria, they were not granted access to the survey. No data was collected from participants regarding demographics, number of years practicing, qualifications, or location of practice.

An email invitation to complete the survey was sent to members of two Special Interest sub-groups of Physiotherapy New Zealand – New Zealand Manipulative Physiotherapists Association (NZMPA) and Sport and Exercise Physiotherapy New Zealand (SEPNZ). Members of these groups were considered more likely to be, or have been, actively involved in the treatment of patients who had undergone ACLR. During the survey period, the survey was also promoted within the NZMPA and SEPNZ groups on a social media platform (Facebook) to increase survey exposure. In an effort to maximise response rates, participants had the option of entering a draw to win a gift card following completion of the survey.

After survey closure, group and individual responses were exported to Microsoft Excel format for examination. A descriptive analysis of the data was performed using SPSS (IBM SPSS Statistics V.26), with the number and percentage of respondents for each answer option calculated. Respondents could select an 'other (please specify)' option for questions 4, 5, 12, 13, and 14. Individual responses for each 'other (please specify)' option were analysed, and if considered appropriate, the response was removed from the 'other (please specify)' option and included in the most suitable answer option for that question.

3. Results

The number of completed surveys was 318, with all questions answered by all respondents. At the time the survey was available for completion, there were 192 members of NZMPA and 890 members of SEPNZ, for an estimated response rate of 29.3% (318/1082). The number of responses and percentages for each question are presented in Table 1. Almost 93% respondents identified their area of expertise as treating all musculoskeletal conditions, with over 90% of respondents treating 20 or less ACLR patients per year.

While 57% of respondents wished to see their patient within a week of ACLR, 28.4% of respondents preferred to wait until 7–14 days after surgery (Table 1). Within the first six weeks of ACLR, over 91% of respondents would see their patients 1–2 times per week. Between 3- and 6-months post-ACLR, 76.2% of respondents would see patients in the clinic at least once per fortnight, with over 20% preferring less frequent visits and a focus on home or gym-based exercises.

Almost all respondents consider rehabilitation essential or important to overall outcome from ACLR at all time points surveyed (Table 1). Between six weeks and three months was the period when the most respondents considered rehabilitation 'essential' (86.8%), compared to six months post-ACLR onwards when the least respondents considered rehabilitation 'essential' (45.3%).

Providing the patient had made satisfactory progress and displayed adequate physical capacity, 63.2% of respondents permitted RTS 9–12 months after ACLR (Table 1). Almost a quarter of respondents (24.2%) would wait 12–18 months after ACLR before supporting RTS, whereas 11% would allow RTS within 6–9 months of surgery. Functional capacity (98.1%), lower limb/trunk mechanics during functional tasks (92.5%), knee strength (90.3%), psychological readiness (89.3%), and time from surgery (75.2%) were the factors most commonly considered before permitting a patient to RTS after ACLR (Table 1).

To evaluate knee strength, 36.2% of respondents estimate strength via other means eg hop tests, while an equal number of respondents use manual muscle testing (MMT) or hand held dynamometry (HDD) (16%) (Table 1). Only 24.5% of respondents use gym-based repetition maximum (RM) testing i.e. 1-10 RM for squat, deadlift, single leg press, knee extension/hamstring curl machine, to assess knee strength when considering RTS. Although respondents could select only one option for question 13 regarding knee strength, the total number of responses for that question exceeds the total number of respondents. The reason for this discrepancy is a large number of respondents selected 'other

Table 1
Questions and responses (n, %) for each item from the anonymous survey.

Q1 What is your primary area of expertise for the purpose of this survey?		
All musculoskeletal conditions	295	93.0%
Primarily lower limb	9	2.8%
Primarily upper limb	2	0.6%
Other sub-specialty, but I still see some ACLR patients	11	3.5%
Other (please specify)	1	0.3%
Q2 Approximately, how many ACLR patients would you see per year?		
1-5	166	52.4%
6-20	131	41.3%
21-50	18	5.7%
>51	3	0.9%
Q3 At what post-operative time-point do you encourage your patient to be seen by you after their ACLR surgery?		
Within the first 1–4 days after surgery.	48	15.1%
Within the first 7 days after surgery.	133	41.9%
Between 1 and 2 weeks after surgery.	90	28.4%
After being cleared by their surgeon.	46	14.5%
When they feel ready to start, though I do not recommend a specific (or ideal) time.	1	0.3%
Q4 How often would you like to see your ACLR patient for supervised rehabilitation, within the first 6 weeks post-surgery?		
Twice per week.	160	50.3%
Once per week.	122	38.3%
Once every two weeks.	9	2.8%
Less frequently if possible, with a focus on home-based exercises and periodic review.	5	2.5%
Other (please specify)		
•Dependent on patients progress, engagement, pre-injury activity level, financial status.	10	3.1%
•1–2 x week.	9	2.8%
•3 x week.	3	0.9%
Q5 Between 3 and 6 months post-surgery, how often would you like to see your ACLR patient within your practice?		
Twice per week.	26	8.2%
Once per week.	88	27.7%
Once every two weeks.	128	40.3%
Less frequently if possible, with a focus on home-based exercises and periodic review.	65	20.4%
Other (please specify)		
•Dependent on patients progress.	6	1.9%
•Every 1–2 weeks.	3	0.9%
Q6 How important do you think 'pre-operative rehabilitation' is to post-operative patient outcome?		
Essential	199	62.8%
Important	116	36.9%
Not important	1	0.3%
No view or opinion	2	0.6%
Q7 How important do you think 'post-operative rehabilitation' is to overall patient outcome within the first 6 weeks post-surgery?		
Essential	247	77.9%
Important	70	22.1%
Not important	1	0.3%
No view or opinion	0	0%
Q8 How important do you think 'post-operative rehabilitation' is to overall patient outcome within 6 weeks to 3 months post-surgery?		
Essential	276	86.8%
Important	41	12.9%
Not important	1	0.3%
No view or opinion	0	0%
Q9 How important do you think 'post-operative rehabilitation' is to overall patient outcome within 3–6 months post-surgery?		
Essential	230	72.3%
Important	83	26.1%
Not important	3	0.9%
No view or opinion	2	0.6%
Q10 How important do you think 'post-operative rehabilitation' is to overall patient outcome from 6 months post-surgery onwards?		
Essential	144	45.3%
Important	157	49.4%
Not important	13	4.1%
No view or opinion	4	1.3%
Q11 Providing you are satisfied with their progress and physical capacity, what time do you typically permit a patient to return to sport (including rugby/league, soccer, netball, touch rugby etc.)?		
6–9 months.	35	11.0%
9–12 months.	201	63.2%
12–18 months.	77	24.2%
≥18 months.	4	1.3%
I tell them they should not return to higher demand sports (e.g. rugby/league, soccer, netball).	1	0.3%
Q12 Given the aforementioned high demand sports, what factors do you personally consider before 'clearing' a patient to return to their sport? (Check all that apply)		
Time from surgery.	239	75.2%
Age of the patient.	141	44.3%
Knee Range of Movement and/or Laxity.	225	70.8%
Patient-reported Outcome Questionnaires.	167	52.5%
Psychological readiness (e.g. confidence, anxiety).	284	89.3%
Knee Strength.	287	90.3%
Functional capacity (e.g. jump and/or hop tests).	312	98.1%
Lower limb and trunk mechanics during jumping/landing task.	294	92.5%

Table 1 (*continued*)

Side-to-side differences in muscular size (i.e. thigh girth).	163	51.3%
Other (please specify)		
•Return to Sport tests/Sport specific tasks.	30	9.4%
•Proprioception/Agility.	8	2.5%
•Cardiovascular fitness.	4	1.3%
•Surgeon clearance.	3	0.9%
•Symptoms eg pain, swelling.	3	0.9%
Q13 If you consider 'knee strength' to be important prior to clearing a patient to return to their sport, how do you evaluate this?		
I use manual muscle testing methods.	51	16.0%
I use hand held dynamometry.	51	16.0%
I use an isokinetic dynamometer.	20	6.3%
I extrapolate/estimate knee strength from other measures such as hop capacity.	115	36.2%
I feel strength is important, but do not have access to necessary equipment (and/or do not feel manual testing methods are accurate enough) so I refer on to someone who can provide this evaluation for me.	24	7.6%
I do not consider these tests that important.	5	1.6%
Other (please specify)		
•Gym based/Repetition Maximum testing.	78	24.5%
Q14 If you consider 'lower limb functional capacity' to be important prior to clearing a patient to return to their sport, how do you evaluate this?		
Star excursion and/or Y-balance test.	12	3.8%
Single limb vertical hop.	5	1.6%
Single limb hop for distance.	20	6.3%
6m timed hop test.	2	0.6%
Triple hop for distance.	16	5.0%
Triple crossover hop for distance.	8	2.5%
A hop test battery (including ≥2 of the 6m timed and single, triple hop and triple crossover hops for distance).	214	67.3%
I do not consider these tests that important.	3	0.9%
Other (please specify)		
•Combination of all the above.	27	8.5%
•Sport specific tasks.	9	2.8%
•Passive range of movement.	2	0.6%

Abbreviations: ACLR — anterior cruciate ligament reconstruction.

(please specify)' and recorded multiple methods of assessing knee strength in their response. Accordingly, and where possible, responses from the 'other (please specify)' option were added to the appropriate answer totals for question 13. To evaluate lower limb functional capacity, 67.3% of respondents use a hop test battery, 16% use only one hop test, and 3.8% use the star excursion balance test (SEBT) and/or Y-balance test (YBT) (Table 1).

4. Discussion

The aim of this study was to gain insights into the current beliefs and practices of NZ physiotherapists regarding rehabilitation and RTS following ACLR. We estimated a survey response rate of 29.3%. Previous surveys of therapists working with ACLR patients have been unable to calculate a response rate (Dingenen et al., 2021; Ebert et al., 2018; Greenberg et al., 2018); however, a recent online survey involving NZ physiotherapists reported a response rate of approximately 10% (Reid et al., 2020).

Successful rehabilitation following ACLR is challenging and should be performed by a clinician with experience in post-ACLR rehabilitation (Buckthorpe, 2019; Filbay & Grindem, 2019). Only 47.6% of respondents in the current study report treating more than six ACLR patients per year, which is less than Australian (74%) and United States (US) therapists (66.7%) (Ebert et al., 2018; Greenberg et al., 2018). Australia has higher rates of ACLR compared to NZ (Zbrojkiewicz et al., 2018), which could contribute to the higher patient numbers in that country. Although rates of ACLR in NZ are now similar to the US (Sutherland et al., 2019), this has not yet translated into NZ physiotherapists treating similar numbers of ACLR patients. Over 90% of respondents indicated they treat all musculoskeletal conditions, suggesting few NZ physiotherapists are specialists, which may further limit clinician experience in ACL rehabilitation.

Post-ACLR rehabilitation should commence immediately following surgery (Filbay & Grindem, 2019; van Melick et al., 2016). Only 57% of respondents in the current survey would see patients in the week following ACLR, which is consistent with Australian (53%) and Flemish (62%) therapists (Dingenen et al., 2021; Ebert et al., 2018). The reasons why a significant percentage of therapists across multiple populations do not commence rehabilitation within the first week of ACLR require further investigation, but could include surgeons not endorsing rehabilitation in the first week following surgery (Feller, Cooper, & Webster, 2002).

Almost 90% of respondents in the current study would see their patient 6–12 times within the first six weeks, and over 77% would see patients 6–24 times between three and six months, which are higher percentages than Australian therapists (82.1% and 58.7%) for the respective time periods (Ebert et al., 2018). It is not clear how frequent respondents would see their patients between six weeks and three months, or from six months onwards, as these periods were not surveyed. Therefore, the majority of respondents in the current survey would see their patients at least 12–36 times within the first six months of ACLR, which is similar to the number of physiotherapy treatments currently suggested following ACLR (Adams et al., 2012; Filbay & Grindem, 2019).

Physiotherapist-led rehabilitation prior to ACLR, and 9–12 months of structured rehabilitation post-ACLR, can optimise patient outcomes (Alshewaier, Yeowell, & Fatoye, 2017; van Melick et al., 2016). Almost all respondents in the current study considered pre-operative rehabilitation essential or important to overall outcome following ACLR — a belief shared by Australian therapists (Ebert et al., 2018). At least 94% of respondents considered rehabilitation essential or important to patient outcomes up to and exceeding six months post-surgery, again similar to Australian therapists (Ebert et al., 2018), but greater than US and Flemish therapists (Dingenen et al., 2021; Greenberg et al., 2018).

Our results suggest NZ physiotherapists are aware of the dosage (quantity and duration) of physiotherapy treatment necessary to achieve optimal patient outcomes – an awareness that does not seem to translate into clinical practice. A recent study showed patients undergoing ACLR in NZ receive an average of 8–12 physiotherapy treatments over an average duration of approximately five months following surgery (Fausett et al., 2019). As such, there is a large discrepancy between the dosage of treatment physiotherapists in NZ believe they are providing following ACLR, and the dosage of physiotherapy treatment actually being provided. ACL rehabilitation in NZ is almost exclusively funded by the Accident Compensation Corporation (ACC) – a government entity that administers a public insurance scheme funding medical treatment and providing compensation following accidents (Flood, 2000). Up until 2019, ACC placed limits on the number of physiotherapy treatments providers could deliver without first seeking prior approval – a barrier that could result in patients receiving a lesser quantity or duration of physiotherapy treatment following ACLR (Fausett et al., 2019). Other possible barriers to receiving the optimal dosage of physiotherapy treatment following ACLR could include economic constraints, decreased patient motivation to complete rehabilitation, decreased patient understanding of rehabilitation requirements, and a lack of surgeon endorsement of rehabilitation (Cailliez et al., 2012; Ebert et al., 2018; Ebert et al., 2018; Fausett et al., 2019). It should be noted the optimal dosage of physiotherapy treatment following ACLR is yet to be established (van Melick et al., 2016; Walker, Hing, & Lorimer, 2020). The overall dosage of physiotherapy treatment following ACLR will be dependent on the treatment plan, with adjustments made according to the progress of the individual patient (Filbay & Grindem, 2019; Wilk & Arrigo, 2017).

A RTS within nine months following ACLR is associated with an increased risk of re-injury (Beischer et al., 2020; Grindem, Snyder-Mackler, Moksnes, Engebretsen, & Risberg, 2016). Over 87% of respondents in the current study reported waiting at least nine months after ACLR before supporting a RTS, which is higher than Australian (77%), Flemish (73%), US (45%) and Brazilian (22% recommend ≥8 months) therapists (Aquino et al., 2020; Dingenen et al., 2021; Ebert et al., 2018; Greenberg et al., 2018). Only 11% of respondents would support a RTS between 6 and 9 months, which is less than Australian (22%), Flemish (25%), and US (38%) therapists (Dingenen et al., 2021; Ebert et al., 2018; Greenberg et al., 2018). Supervised rehabilitation after ACLR that exceeds 6 months is associated with increased knee strength, improved functional capacity, and greater limb symmetry (Ebert, Edwards, et al., 2018; Edwards et al., 2018; Królikowska, Sikorski, Czamara, & Reichert, 2018) – factors that also decrease the risk of graft rupture and increase the likelihood of a successful RTS (Kyritsis, Bahr, Landreau, Miladi, & Witvrouw, 2016; Meredith et al., 2020). Although criterion-based measures are now recommended over time-based measures following ACLR (Adams et al., 2012), time from surgery and duration of rehabilitation likely influence patient outcomes. Our results indicate the majority of NZ physiotherapists endorse a RTS timeframe consistent with current evidence, while also being more aware of the importance of 'time from surgery' when considering RTS following ACLR than overseas counterparts.

Physical capacity, movement quality, psychological readiness, and biological healing are factors recommended to consider when evaluating a patient for RTS following ACLR (Filbay & Grindem, 2019; van Melick et al., 2016). The factors NZ physiotherapists consider when evaluating a patient for RTS align with current recommendations, and are also consistent with factors considered by Australian, Flemish, and Brazilian therapists (Aquino et al., 2020; Dingenen et al., 2021; Ebert et al., 2018). Successful RTS following ACLR includes achieving the pre-injury level of activity, as defined by the same type, frequency, intensity and quality of performance (Meredith et al., 2020). A multidisciplinary team, including the physiotherapist, should be involved in any RTS decision (Meredith et al., 2020). However, NZ physiotherapists may not be actively involved in patient management at the time of RTS, as the duration of physiotherapy treatment in NZ after ACLR does not often extend to the time-point where patients are potentially contemplating a RTS (Fausett et al., 2019).

Just over one third of respondents report estimating knee strength from functional measures such as hop capacity, which is less than Australian therapists (48.9%) (Ebert et al., 2018). Caution should be used when using hop tests in this way, as results from functional tests do not always correlate with objective measures of knee strength (Toole et al., 2017), leading to a possible overestimation of knee strength. Manual muscle testing (MMT) and hand held dynamometry (HDD) were also commonly reported methods to evaluate knee strength – consistent with US therapists (Greenberg et al., 2018) but less often than Australian therapists (Ebert et al., 2018). MMT and HDD require little resource, which likely contributes to their popularity, although their accuracy may be less than other methods (Bohannon, 2005; Sinacore et al., 2017). The reliability of gym-based repetition maximum (RM) tests are similar to MMT and HDD (Sinacore et al., 2017). However, only one in four respondents in the current study report using gym-based RM testing to evaluate knee strength – a similar number to US therapists (Greenberg et al., 2018). Isokinetic evaluation of knee strength remains the gold standard but utilisation of this by NZ and Australian therapists is low, likely due to cost and availability (Ebert et al., 2018). Overall, the methods reportedly used by the majority of NZ physiotherapists to evaluate knee strength after ACLR could lead to an inaccurate assessment of strength. An incorrect estimation of knee strength could lead to an insufficient rehabilitation stimulus to promote functional improvement, the prescription of rehabilitation exercises that exceed the patients true functional ability, or a premature return to pre-injury activities (Beischer, Senorski, Thomeé, Samuelsson, & Thomeé, 2018; Filbay & Grindem, 2019). Given the positive relationship between knee strength and patient outcomes following ACLR (Arhos et al., 2020; Cristiani et al., 2020), there appears considerable scope for improvement in the assessment of knee strength by NZ physiotherapists.

Approximately 75% of respondents in the current study reported using a hop test battery to evaluate lower limb functional capacity for RTS, which compares favourably to Australian (84.3%) and US therapists (79.4%) (Ebert et al., 2018; Greenberg et al., 2018). Hop tests are commonly used in the clinic setting, as they are relatively easy to administer, and produce valid, reliable results (Reinke et al., 2011). A hop test battery should be utilised when considering a RTS following ACLR (Ardern et al., 2016; van Melick et al., 2016), and greater performance during hop tests can be associated with improved patient outcomes (Edwards et al., 2018; Kyritsis et al., 2016). Measuring only quantitative performance during hop tests maybe insufficient to fully assess knee function after ACLR (Kotsifaki, Korakakis, Whiteley, Van Rossom, & Jonkers, 2020; Nagai, Schilaty, Laskowski, & Hewett, 2020). A 'quality' assessment of movement performance during hop tests is recommended (Davies, Myer, & Read, 2020), as meeting RTS criterion on a quality measure is associated with a lower second ACL injury rate (van Melick et al., 2021). Of note is the 25% of respondents in the current study who report not using a hop test battery. Using only one hop test to asses lower limb functional capacity could result in a sub-optimal assessment of physical performance and compromise RTS, as no single hop test can consistently predict RTS or risk of re-injury (Davies et al., 2020).

Only 12.3% of respondents report using the star excursion balance test (SEBT) and/or Y-balance test (YBT) to assess functional

capacity when considering RTS following ACLR, compared to 62.8% and 48.8% of Australian and US therapists respectively (Ebert et al., 2018; Greenberg et al., 2018). As performance on the SEBT in ACLR patients at the time of RTS has been shown to be worse compared to uninjured controls (Clagg, Paterno, Hewett, & Schmitt, 2015), increased utilisation of balance tests by NZ physiotherapists when evaluating lower limb function may be indicated. The reasons for the low utilisation of balance tests by NZ physiotherapists compared to overseas counterparts are not entirely clear. In contrast to the original survey of Ebert et al., respondents were limited to one selection for the question regarding methods to assess lower limb functional capacity. Therefore, the low reported usage of balance tests may be an underestimation, as more respondents could have selected hop tests as they considered these more important, despite in fact using balance tests to asses functional capacity.

5. Limitations

A number of limitations with the current study can be identified. Despite all NZMPA and SEPNZ members being notified of the survey, the estimated response rate was approximately 30%. A low survey response rate can introduce bias and compromise the validity of the results. Due to unrestricted access to the survey via social media, we cannot exclude the possibility NZ physiotherapists who are non-members of NZMPA or SEPNZ completed the survey, although this is unlikely to be a significant number. Although there are over 4000 registered physiotherapists in NZ, we limited promotion of the survey to specific groups of physiotherapists in NZ, which potentially constrained both the number and diversity of responses. In the current study, respondents were restricted to NZ registered physiotherapists, but in the original study the survey was sent to members of the Australian Physiotherapy Association and Exercise and Sport Science Australia, as members of both groups are involved in delivering post-ACLR rehabilitation (Ebert et al., 2018). Different training between the professions and diverse practice beliefs between the study populations could have contributed to discrepancies between the results. It is possible some respondents in the current study answered questions from a 'what is *best* clinical practice' perspective, rather than 'what is *actual* clinical practice' perspective, which could explain some of the variability in the results. No data was collected regarding participant demographics and practice variables (number of years practicing, qualifications, location of practice etc), and the absence of such information may limit the overall generalisability of the results. Participant anonymity is required for ethical approval; however, the lack of a participant specific log-in could, in theory, permit multiple responses from the same participant. Although SurveyMonkey will not allow the survey to be completed on multiple occasions from the same computer and internet browser, it is not possible to say whether participants accessed the survey multiple times via different internet browsers.

6. Conclusion

Results of this survey revealed variability amongst NZ physiotherapists regarding rehabilitation and RTS practices and beliefs following ACLR. The need for pre-and post-ACLR rehabilitation is well recognised amongst physiotherapists, and although the majority of respondents report practice beliefs consistent with current recommendations, it is not clear if those beliefs are consistent with clinical practice. The commencement of post-ACLR rehabilitation and frequency of patient visits is varied, with multiple factors likely influencing the overall dosage of physiotherapy treatment. Areas for future research include exploring discrepancies between therapist beliefs regarding ACLR rehabilitation and objective treatment data, investigating barriers to delays in commencing rehabilitation following ACLR, increasing the usability of clinical practice guidelines, and improving access to appropriate methods to assess knee strength and RTS testing following ACLR.

Ethics statement

Ethical approval for this research was obtained from the Auckland University of Technology Ethics Committee (AUTEC); approval number 20/106.

Declaration of competing interest

None.

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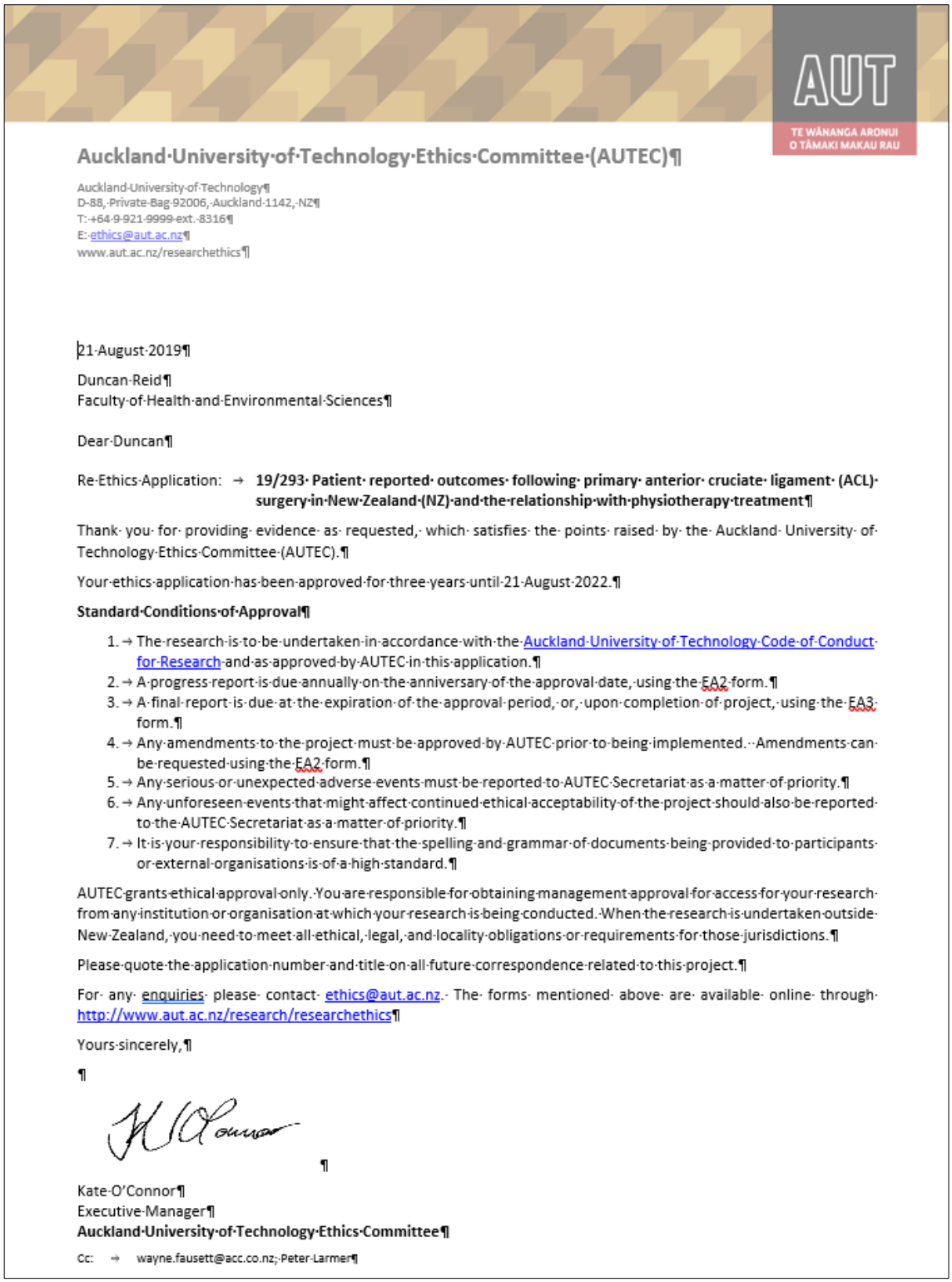
Appendix E.
Ethics approval: Chapter 4.



AUT
TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

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21 August 2019

Duncan Reid
Faculty of Health and Environmental Sciences

Dear Duncan

Re Ethics Application: **19/293 Patient reported outcomes following primary anterior cruciate ligament (ACL) surgery in New Zealand (NZ) and the relationship with physiotherapy treatment**

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 21 August 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 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.

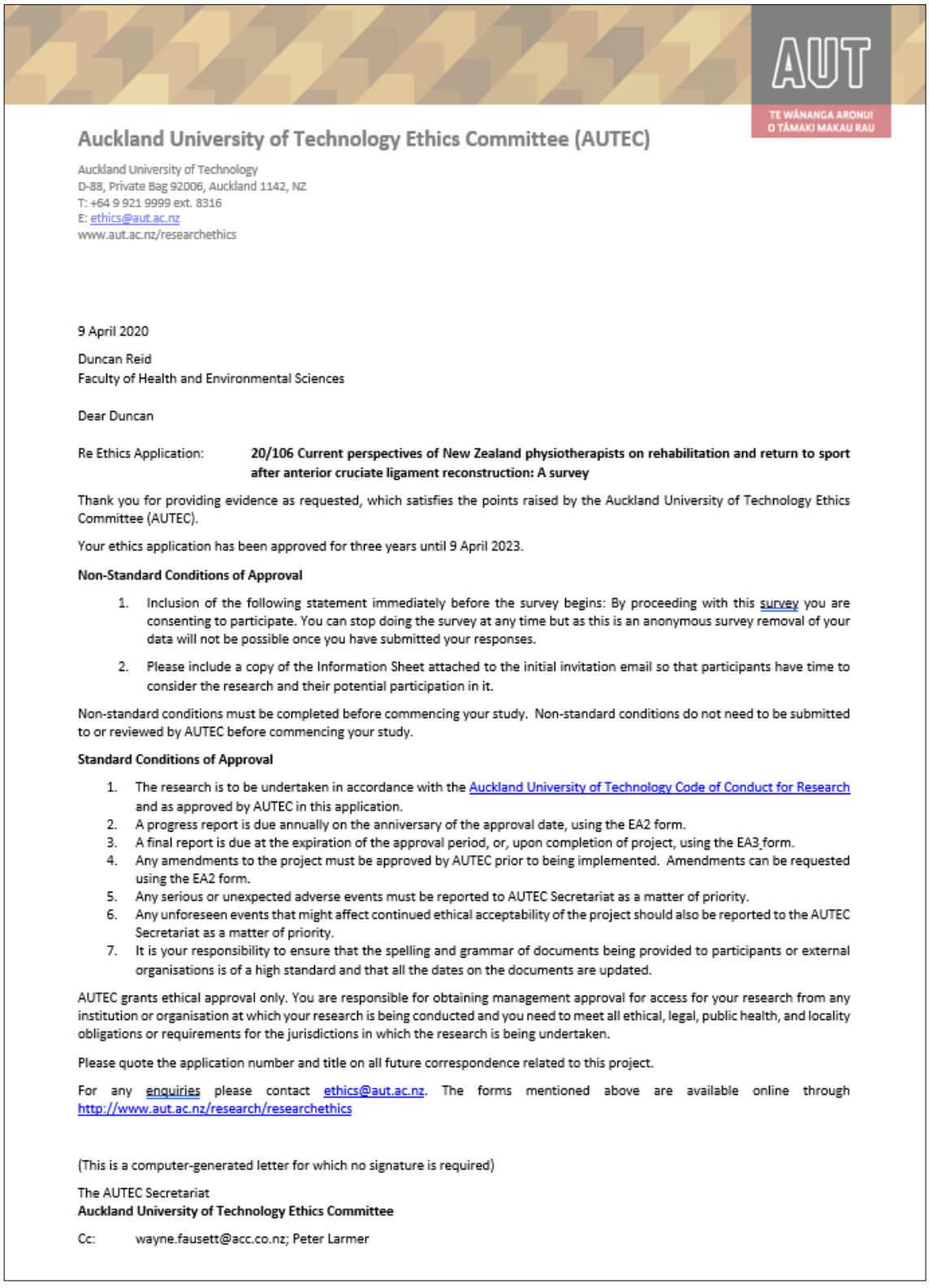
For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

Yours sincerely,

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: wayne.fausett@acc.co.nz; Peter Larmer

Appendix F.
Ethics approval: Chapter 5.



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

9 April 2020

Duncan Reid
Faculty of Health and Environmental Sciences

Dear Duncan

Re Ethics Application: **20/106 Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport after anterior cruciate ligament reconstruction: A survey**

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 9 April 2023.

Non-Standard Conditions of Approval

1. Inclusion of the following statement immediately before the survey begins: By proceeding with this survey you are consenting to participate. You can stop doing the survey at any time but as this is an anonymous survey removal of your data will not be possible once you have submitted your responses.
2. Please include a copy of the Information Sheet attached to the initial invitation email so that participants have time to consider the research and their potential participation in it.

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.

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 and that all the dates on the documents are updated.

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 and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

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: wayne.fausett@acc.co.nz; Peter Larmer

Appendix G.
Knee Injury and Osteoarthritis Outcome Score questionnaire.

KOOS KNEE SURVEY

Today's date: _____/_____/_____ Date of birth: _____/_____/_____

Name: _____

INSTRUCTIONS: This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to perform your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

Symptoms
These questions should be answered thinking of your knee symptoms during the **last week**.

S1. Do you have swelling in your knee?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S2. Do you feel grinding, hear clicking or any other type of noise when your knee moves?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S3. Does your knee catch or hang up when moving?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S4. Can you straighten your knee fully?

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

S5. Can you bend your knee fully?

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

Stiffness
The following questions concern the amount of joint stiffness you have experienced during the **last week** in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

S6. How severe is your knee joint stiffness after first wakening in the morning?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

S7. How severe is your knee stiffness after sitting, lying or resting **later in the day**?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Pain

P1. How often do you experience knee pain?

Never	Monthly	Weekly	Daily	Always
☐	☐	☐	☐	☐

What amount of knee pain have you experienced the **last week** during the following activities?

P2. Twisting/pivoting on your knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P3. Straightening knee fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P4. Bending knee fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P5. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P6. Going up or down stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P7. At night while in bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P8. Sitting or lying

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P9. Standing upright

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, daily living

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A1. Descending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A2. Ascending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A3. Rising from sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A4. Standing

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A5. Bending to floor/pick up an object

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A6. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A7. Getting in/out of car

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A8. Going shopping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A9. Putting on socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A10. Rising from bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A11. Taking off socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A12. Lying in bed (turning over, maintaining knee position)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A13. Getting in/out of bath

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A14. Sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A15. Getting on/off toilet

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A17. Light domestic duties (cooking, dusting, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, sports and recreational activities

The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your knee.

SP1. Squatting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP2. Running

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP3. Jumping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP4. Twisting/pivoting on your injured knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP5. Kneeling

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Quality of Life

Q1. How often are you aware of your knee problem?

Never	Monthly	Weekly	Daily	Constantly
☐	☐	☐	☐	☐

Q2. Have you modified your life style to avoid potentially damaging activities to your knee?

Not at all	Mildly	Moderately	Severely	Totally
☐	☐	☐	☐	☐

Q3. How much are you troubled with lack of confidence in your knee?

Not at all	Mildly	Moderately	Severely	Extremely
☐	☐	☐	☐	☐

Q4. In general, how much difficulty do you have with your knee?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Appendix H.
Marx Activity Rating Scale

MARX SCALE (ENGLISH VERSION)

Please indicate how often you performed each activity in your healthiest and most active state, in the past year. Kindly put a (☑) mark on the appropriate space after each item.

	Less than one time in a month	One time in a month	One time in a week	2 or 3 times in a week	4 or more times in a week
Running: running while playing a sport or jogging	0	1	2	3	4
Cutting: changing directions while running	0	1	2	3	4
Deceleration: coming to a quick stop while running	0	1	2	3	4
Pivoting: turning your body with your foot planted while playing sport; For example: skiing, skating, kicking, throwing, hitting a ball (golf, tennis, squash), etc.	0	1	2	3	4

Appendix I.
Example of the search strategy for PubMed.

Search	Actions	Details	Query	Results
#21	•••	›	Search: **#11 AND #12 AND #13 AND #19 AND #20** Sort by: **Publication Date**	10
#20	•••	›	Search: **#16 OR #17 OR #18** Sort by: **Publication Date**	94,629
#19	•••	›	Search: **#1 OR #15** Sort by: **Publication Date**	1,973,391
#18	•••	›	Search: **"home based"[Title/Abstract]** Sort by: **Publication Date**	12,223
#17	•••	›	Search: **unsupervis*[Title/Abstract]** Sort by: **Publication Date**	14,364
#16	•••	›	Search: **supervis*[Title/Abstract]** Sort by: **Publication Date**	73,274
#15	•••	›	Search: **outcome*[Title/Abstract]** Sort by: **Publication Date**	1,973,391
#14	•••	›	Search: **#1 AND #11 AND #12 AND #13** Sort by: **Publication Date**	0
#13	•••	›	Search: **#9 OR #10** Sort by: **Publication Date**	725,572
#12	•••	›	Search: **#6 OR #7 OR #8** Sort by: **Publication Date**	26,002
#11	•••	›	Search: **#3 OR #4 OR #5** Sort by: **Publication Date**	217,454
#10	•••	›	Search: **quantity[Title/Abstract]** Sort by: **Publication Date**	91,189
#9	•••	›	Search: **duration[Title/Abstract]** Sort by: **Publication Date**	637,769
#8	•••	›	Search: **"anterior cruciate ligament reconstruction"[Title/Abstract]** Sort by: **Publication Date**	7,687
#7	•••	›	Search: **"anterior cruciate ligament"[Title/Abstract]** Sort by: **Publication Date**	20,602
#6	•••	›	Search: **ACL[Title/Abstract]** Sort by: **Publication Date**	18,283
#5	•••	›	Search: **rehabilitation[Title/Abstract]** Sort by: **Publication Date**	183,432
#4	•••	›	Search: **"physical therapy"[Title/Abstract]** Sort by: **Publication Date**	23,256
#3	•••	›	Search: **physiotherapy[Title/Abstract]** Sort by: **Publication Date**	22,070
#1	•••	›	Search: **"patient reported outcome measures"[Title/Abstract]** Sort by: **Publication Date**	6,433

Appendix J.
Odds Ratios for the likelihood of achieving a KOOS[4] PASS score.

			Unadjusted*			Adjusted**		
			OR	95% CI	p-value	OR	95% CI	p-value
Time	Pre-Surgery		1.00			1.00		
	0-6 months		5.34	(4.92,5.79)		6.37	(4.76,8.53)	
	7-12 months		10.87	(9.96,11.86)		13.92	(10.55,18.35)	
	13-24 months		13.99	(12.64,15.49)	<.0001	16.08	(11.63,22.22)	<.0001
Time x Gender	Pre-Surgery	Female	0.72	(0.62,0.83)		0.67	(0.58,0.78)	
	Pre-Surgery	Male	1.00			1.00		
	0-6 months	Female	0.79	(0.70,0.88)		0.72	(0.64,0.82)	
	0-6 months	Male	1.00			1.00		
	7-12 months	Female	0.98	(0.86,1.11)		0.89	(0.78,1.02)	
	7-12 months	Male	1.00			1.00		
	13-24 months	Female	1.06	(0.90,1.25)		1.00	(0.84,1.18)	
	13-24 months	Male	1.00		<.0001	1.00		<.0001
Time x Age at date of ACLR	Pre-Surgery	8-20 years	1.00			1.00		
	Pre-Surgery	21-30 years	0.70	(0.58,0.83)		0.72	(0.60,0.87)	
	Pre-Surgery	31-40 years	0.57	(0.46,0.71)		0.56	(0.45,0.70)	
	Pre-Surgery	41-69 years	0.47	(0.37,0.59)		0.46	(0.37,0.58)	
	0-6 months	8-20 years	1.00			1.00		
	0-6 months	21-30 years	0.68	(0.58,0.79)		0.76	(0.64,0.89)	
	0-6 months	31-40 years	0.59	(0.50,0.71)		0.66	(0.55,0.79)	
	0-6 months	41-69 years	0.63	(0.53,0.76)		0.69	(0.58,0.83)	
	7-12 months	8-20 years	1.00			1.00		
	7-12 months	21-30 years	0.75	(0.63,0.90)		0.87	(0.72,1.05)	
	7-12 months	31-40 years	0.52	(0.43,0.64)		0.63	(0.52,0.78)	
	7-12 months	41-69 years	0.65	(0.53,0.79)		0.76	(0.62,0.94)	
	13-24 months	8-20 years	1.00			1.00		
	13-24 months	21-30 years	0.79	(0.62,0.99)		0.90	(0.71,1.14)	
	13-24 months	31-40 years	0.65	(0.51,0.83)		0.77	(0.60,1.00)	
	13-24 months	41-69 years	0.87	(0.68,1.12)	<.0001	0.99	(0.77,1.29)	<.0001
Time x Any Physiotherapy Treatment	Pre-Surgery	No	1.00			1.00		
	0-6 months	Yes	1.12	(0.95,1.31)		1.19	(1.01,1.41)	
	0-6 months	No	1.00			1.00		
	7-12 months	Yes	1.21	(1.08,1.36)		1.18	(1.05,1.33)	
	7-12 months	No	1.00			1.00		
	13-24 months	Yes	0.86	(0.68,1.09)		0.84	(0.67,1.07)	
	13-24 months	No	1.00		0.0024	1.00		0.0035
Time x Vocational Rehabilitation	Pre-Surgery	Yes	0.64	(0.54,0.75)		0.69	(0.59,0.82)	
	Pre-Surgery	No	1.00			1.00		
	0-6 months	Yes	0.57	(0.5,0.64)	<.0001	0.60	(0.52,0.68)	<.0001

			Unadjusted*			Adjusted**		
			OR	95% CI	p-value	OR	95% CI	p-value
Time x Days from ACL Injury to ACLR	0-6 months	No	1.00			1.00		
	7-12 months	Yes	0.56	(0.49,0.64)		0.59	(0.52,0.68)	
	7-12 months	No	1.00			1.00		
	13-24 months	Yes	0.61	(0.52,0.72)		0.63	(0.53,0.75)	
	13-24 months	No	1.00			1.00		
	Pre-Surgery	14-79	1.00			1.00		
	Pre-Surgery	80-126	1.61	(1.29,2.01)		1.62	(1.29,2.02)	
	Pre-Surgery	127-230	1.84	(1.48,2.29)		1.94	(1.56,2.42)	
	Pre-Surgery	230+	2.11	(1.70,2.61)		2.27	(1.83,2.81)	
	0-6 months	14-79	1.00			1.00		
	0-6 months	80-126	1.08	(0.92,1.27)		1.07	(0.91,1.26)	
	0-6 months	127-230	1.19	(1.01,1.40)		1.23	(1.04,1.45)	
	0-6 months	230+	1.27	(1.08,1.50)		1.31	(1.1,1.55)	
	7-12 months	14-79	1.00			1.00		
	7-12 months	80-126	1.12	(0.93,1.34)		1.13	(0.94,1.36)	
	7-12 months	127-230	0.95	(0.79,1.14)		0.98	(0.82,1.18)	
	7-12 months	230+	0.91	(0.76,1.09)		0.93	(0.78,1.12)	
	13-24 months	14-79	1.00			1.00		
	13-24 months	80-126	1.17	(0.92,1.48)		1.16	(0.92,1.47)	
	13-24 months	127-230	1.03	(0.82,1.29)		1.03	(0.82,1.30)	
	13-24 months	230+	0.94	(0.75,1.17)	<.0001	0.91	(0.72,1.14)	<.0001

*unadjusted except for time effects

**adjusted for gender, age at date of ACLR, presence of vocational rehabilitation post-ACLR, and number of days between ACL injury and ACLR.

Appendix K.
Odds Ratios for the likelihood of achieving a normative MARS score.

			Unadjusted*			Adjusted**		
			OR	95% CI	p-value	OR	95% CI	p-value
Time	Pre-Surgery		1.00			1.00		
	0-6 months		2.20	(1.90,2.55)		14.66	(6.66,32.28)	
	7-12 months		5.86	(5.10,6.73)		37.85	(18.37,77.96)	
	13-24 months		7.53	(6.52,8.7)	<.0001	35.14	(16.75,73.73)	<.0001
Time x Gender	Pre-Surgery	Female	0.85	(0.65,1.09)		0.80	(0.62,1.04)	
	Pre-Surgery	Male	1.00			1.00		
	0-6 months	Female	0.82	(0.68,1.00)		0.75	(0.62,0.92)	
	0-6 months	Male	1.00			1.00		
	7-12 months	Female	0.74	(0.64,0.85)		0.65	(0.55,0.75)	
	7-12 months	Male	1.00			1.00		
	13-24 months	Female	0.77	(0.65,0.90)		0.70	(0.59,0.84)	
	13-24 months	Male	1.00		0.0001	1.00		<.0001
Time x Age at date of ACLR	Pre-Surgery	8-20 years	1.00			1.00		
	Pre-Surgery	21-30 years	0.53	(0.40,0.71)		0.54	(0.40,0.74)	
	Pre-Surgery	31-40 years	0.42	(0.29,0.62)		0.45	(0.31,0.67)	
	Pre-Surgery	41-69 years	0.23	(0.14,0.38)		0.31	(0.19,0.51)	
	0-6 months	8-20 years	1.00			1.00		
	0-6 months	21-30 years	0.47	(0.37,0.58)		0.49	(0.39,0.62)	
	0-6 months	31-40 years	0.24	(0.18,0.34)		0.27	(0.19,0.38)	
	0-6 months	41-69 years	0.20	(0.14,0.28)		0.25	(0.17,0.36)	
	7-12 months	8-20 years	1.00			1.00		
	7-12 months	21-30 years	0.56	(0.47,0.66)		0.64	(0.53,0.77)	
	7-12 months	31-40 years	0.28	(0.22,0.35)		0.35	(0.28,0.45)	
	7-12 months	41-69 years	0.16	(0.12,0.20)		0.22	(0.17,0.29)	
	13-24 months	8-20 years	1.00			1.00		
	13-24 months	21-30 years	0.69	(0.56,0.85)		0.73	(0.59,0.91)	
	13-24 months	31-40 years	0.34	(0.26,0.44)		0.38	(0.29,0.50)	
	13-24 months	41-69 years	0.18	(0.13,0.24)	<.0001	0.23	(0.17,0.32)	<.0001
Time x Any Physiotherapy Treatment	Pre-Surgery	No	1.00			1.00		
	0-6 months	Yes	0.95	(0.71,1.27)		0.91	(0.68,1.23)	
	0-6 months	No	1.00			1.00		
	7-12 months	Yes	1.27	(1.12,1.46)		1.13	(0.97,1.31)	
	7-12 months	No	1.00			1.00		
	13-24 months	Yes	1.40	(1.12,1.75)		1.24	(0.97,1.58)	
	13-24 months	No	1.00		0.0003	1.00		0.15
Time x Vocational Rehabilitation	Pre-Surgery	Yes	0.81	(0.61,1.06)		1.04	(0.77,1.38)	
	Pre-Surgery	No	1.00			1.00		
	0-6 months	Yes	0.65	(0.52,0.8)		0.85	(0.68,1.07)	
	0-6 months	No	1.00			1.00		
	7-12 months	Yes	0.51	(0.43,0.59)	<.0001	0.57	(0.48,0.68)	

			Unadjusted*			Adjusted**		
			OR	95% CI	p-value	OR	95% CI	p-value
Time x Days from ACL Injury to ACLR	7-12 months	No	1.00			1.00		
	13-24 months	Yes	0.77	(0.65,0.92)		0.89	(0.73,1.08)	
	13-24 months	No	1.00			1.00		<.0001
	Pre-Surgery	14-79	1.00			1.00		
	Pre-Surgery	80-126	1.14	(0.8,1.62)		1.20	(0.84,1.72)	
	Pre-Surgery	127-230	1.00	(0.69,1.44)		1.16	(0.8,1.69)	
	Pre-Surgery	230+	1.10	(0.77,1.57)		1.39	(0.97,2.01)	
	0-6 months	14-79	1.00			1.00		
	0-6 months	80-126	0.94	(0.73,1.21)		0.98	(0.76,1.27)	
	0-6 months	127-230	0.73	(0.56,0.95)		0.82	(0.62,1.07)	
	0-6 months	230+	0.61	(0.46,0.8)		0.72	(0.54,0.97)	
	7-12 months	14-79	1.00			1.00		
	7-12 months	80-126	0.79	(0.65,0.95)		0.81	(0.66,0.99)	
	7-12 months	127-230	0.47	(0.39,0.58)		0.50	(0.41,0.62)	
	7-12 months	230+	0.45	(0.37,0.56)		0.52	(0.42,0.65)	
	13-24 months	14-79	1.00			1.00		
	13-24 months	80-126	0.91	(0.73,1.14)		0.96	(0.76,1.22)	
	13-24 months	127-230	0.65	(0.52,0.81)		0.71	(0.56,0.91)	
	13-24 months	230+	0.51	(0.4,0.64)	<.0001	0.60	(0.47,0.77)	<.0001

*unadjusted except for time effects

**adjusted for gender, age at date of ACLR, presence of vocational rehabilitation post-ACLR, and number of days between ACL injury and ACLR.

Appendix L.
Participant information sheet: Chapter 5.

AUT
TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Participant Information Sheet

Date Information Sheet Produced:

19/03/2020

Project Title

Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport after anterior cruciate ligament (ACL) reconstruction: A survey.

An Invitation

My name is Wayne Fausett and I am completing a Doctor of Health Science degree at AUT. As part of my thesis, I am conducting a survey of New Zealand physiotherapists to establish their beliefs and practices regarding rehabilitation and physiotherapy treatment after ACL reconstruction surgery. As you are a New Zealand registered physiotherapist, I would like to invite you to participate in the survey. Your participation is entirely voluntary, and whether you choose to participate or not, you will be neither advantaged nor disadvantaged in any way.

What is the purpose of this research?

Functional rehabilitation is an essential component of the overall rehabilitation programme following anterior cruciate ligament (ACL) surgery. Physiotherapist beliefs regarding ACL rehabilitation are generally consistent with best-practice recommendations. However, recent evidence suggests the amount of physiotherapy treatment patients are receiving following ACL surgery does not match the amount of treatment physiotherapists believe patient should be receiving.

The aims of this research are twofold:

1. To gain insights into current beliefs and practices of New Zealand physiotherapists regarding treatment and rehabilitation following primary ACL surgery.
2. To compare and contrast the self-reported beliefs and practices of NZ physiotherapists regarding treatment after ACL surgery with objective physiotherapy treatment data after ACL surgery.

The results of this research will contribute to the thesis component of my Doctor of Health Science degree, and the findings of this research may also be used for academic publications and presentations.

How was I identified and why am I being invited to participate in this research?

You have been invited to participate in this research as you have identified yourself as a New Zealand registered physiotherapist with a current annual practicing certificate (APC). In New Zealand, physiotherapists are the main providers of functional rehabilitation for people who have undergone ACL surgery, and will therefore likely have knowledge and experience regarding ACL rehabilitation. As a physiotherapist who is currently treating, or has previously treated, patients after ACL surgery, you are eligible to participate in the research. If, as a physiotherapist, you have never treated a person with an ACL injury, you will not be able to participate in this research.

How do I agree to participate in this research?

If you agree to participate in this research, please provide your consent by checking the appropriate box below. Your participation in this research is entirely voluntary (it is your choice), and whether or not you choose to participate will neither advantage nor disadvantage you.

What will happen in this research?

As a participant, you will be required to complete an anonymous, online survey about your beliefs and practices regarding treatment and rehabilitation for patients before and after ACL surgery. The survey will include questions regarding the timing, frequency, and duration of pre- and post-operative ACL physiotherapy treatment and rehabilitation. It is expected the survey will take approximately 5-10 minutes to complete.

Survey results will be then compared with results from previous surveys of physiotherapists regarding ACL rehabilitation to determine if NZ physiotherapists' beliefs are comparable with overseas groups. Survey results will also be compared with best-practice recommendations to determine if the beliefs of NZ physiotherapists are consistent with recommended guidelines.

Results from the survey will also be compared to physiotherapy treatment data from ACC claims where there is a completed ACL surgery to make comparisons between what NZ physiotherapists believe what physiotherapy

treatment and rehabilitation people should receive following ACL surgery, and what ACC-funded physiotherapy treatment patients actually did receive following ACL surgery.

What are the discomforts and risks?

No discomfort or risk to any participant are expected or anticipated.

How will these discomforts and risks be alleviated?

In the unlikely event of a participant suffering any discomfort or untoward negative response after completing the survey, AUT Health Counselling and Wellbeing is able to offer three free sessions of confidential counselling support for adult participants in an AUT research project. These sessions are only available for issues that have arisen directly as a result of participation in the research, and are not for other general counselling needs. To access these services, you will need to:

- drop into our centres at WB219 or AS104 or phone 921 9992 City Campus or 921 9998 North Shore campus to make an appointment. Appointments for South Campus can be made by calling 921 9992
- let the receptionist know that you are a research participant, and provide the title of my research and my name and contact details as given in this Information Sheet

You can find out more information about AUT counsellors and counselling on http://www.aut.ac.nz/being-a-student/current-postgraduates/your-health-and-wellbeing/counselling.

What are the benefits?

As physiotherapists, participants will have an opportunity to reflect on their clinical practice regarding ACL rehabilitation, which may lead to participants incorporating more evidence-based interventions into their practice. Reflective practice by NZ physiotherapists can direct positive change in clinical practice, which may improve rehabilitation interventions and patient outcomes after ACL injury, benefiting the wider community overall.

This research will allow a better understanding of NZ physiotherapist beliefs regarding ACL rehabilitation, which may act as a benchmark for initiating discussions with the physiotherapy community regarding physiotherapeutic management of ACL injuries.

How will my privacy be protected?

The online survey will be completely anonymous. You will not be required to submit any personal information that could potentially identify you in any way.

If you wish to go into a draw to win one of six $250 gift cards, you will be required to submit your name and a contact email address at the conclusion of the survey. Your name and email address will not be linked to your survey responses in any way.

What are the costs of participating in this research?

There is no financial cost to you for participating in this research.

What opportunity do I have to consider this invitation?

The survey will be available for completion between June 1st 2020 and October 31st 2020.

Will I receive feedback on the results of this research?

Once the results of the survey are available, an url will be made available to all participants to access the results.

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, Prof. Duncan Reid, duncan.reid@aut.ac.nz, (09) 921 9999 ext 7806.

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 for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Wayne Fausett, wayne.fausett@acc.co.nz, (07) 579 0326

Project Supervisor Contact Details:

Prof. Duncan Reid, duncan.reid@aut.ac.nz, (09) 921 9999 ext 7806