

**Physical activity profiling of New Zealand adults:  
A study of adults with and without young children**

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## List of Abbreviations

Abbreviation	Definition
ACSM	American College of Sports Medicine
ALSWH	Australian Longitudinal Study of Women's Health
AUTEC	Auckland University of Technology Ethics Committee
AWAS	Australian Women's Activity Survey
CPM	Counts per minute
CDC	Centers for Disease Control and Prevention
IPAQ	International Physical Activity Questionnaire
IPAQ-LF	International Physical Activity Questionnaire, Long form
IQR	Interquartile Range
LTEQ	Leisure-Time Exercise Questionnaire
MET	Metabolic equivalent
MNYC	Men with no young children
MPA	Moderate physical activity
MUCEHN	Massey University Human Ethics Committee: Northern
MVPA	Moderate-to-vigorous physical activity
MYC	Men with young children
SAS	Statistical Analysis System
PAR	7 day Physical Activity Recall
URBAN	Understanding Relationships Between Activity and Neighbourhoods
VPA	Vigorous physical activity
WNYC	Women with no young children
WYC	Women with young children

## Nomenclature

Term/Symbol	Definition
CI	Confidence Interval
$d$	Cohen's measure of effect size
$df$	Degrees of freedom
ICC	Intraclass Correlation
kg	kilogram
lb	pound
Mph	Miles per hour
$n$	Number of cases in a subsample
$N$	Total number of cases
OR	Odds ratio
%	Percentage
$\pm$	plus-minus
$p$	p-value, statistical significance
$r$	Pearson correlation coefficient
$r_s$	Spearman rank order coefficient
$SD$	standard deviation
$t$	$t$ -test statistic
$\chi^2$	Chi-square test statistic



## List of Publications Arising from Doctoral Thesis

### ***Peer-reviewed Journal Publications***

Papers published

Mackay, L. M., Schofield, G. M., & Oliver, M. (2011). Measuring physical activity and sedentary behaviors in women with young children: A systematic review. *Women and Health*, 51, 400–421. doi: 10.1080/03630242.2011.574794

Mackay, L. M., Schofield, G. M., & Oliver, M. (2011). Demographic variations in discrepancies between objective and subjective measures of physical activity. *Open Journal of Preventive Medicine*, 1, 13–19. doi: 10.4236/ojpm.2011.12003

Papers in preparation for submission

Mackay, L. M., Schofield, G. M., Oliver, M., & Hopkins, W. G. (in preparation for submission). Physical activity at sedentary, light, and moderate-to-vigorous intensities: A study of adults with and without young children

Mackay, L. M., Schofield, G. M., & Oliver, M. (in preparation for submission). Hour-by-hour physical activity profiles: A study of adults with and without young children

Mackay, L. M., Schofield, G. M., Oliver, M., & Hopkins, W. G. (in preparation for submission). Patterns of physical activity and sedentary time: A study of adults with and without young children

### ***Peer-reviewed Conference Presentations***

Mackay, L. M., Schofield, G. M., & Oliver, M. (2011). *Effect of young children on women's objectively assessed physical activity*. Paper presented at the 2011 Satellite Meeting of the International Society for Behavioral Nutrition and Physical Activity, Beyond 2011: New paradigms to Improve Physical Activity and Nutrition, Queenstown, New Zealand.

## **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.

Chapters 3–7 have been submitted (or are in the process of being prepared for submission) for consideration as separate papers for publication in international peer-reviewed journals. Each of these papers was conceived by the candidate, who was also the main contributor and principal author. All co-authors have approved the inclusion of the papers they were involved in as chapters for this thesis. Individual contributions for these chapters are outlined in the introduction (Chapter 1).

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## Thesis Abstract

Physical activity is essential for optimal health and wellbeing for all people. Emerging epidemiological perspectives call for a move from the current focus on moderate-to-vigorous physical activity (MVPA) to a whole-of-physical activity approach, where understanding of physical activity accumulated in all areas of life and at all intensities is important. A key driver of this perspective has been developments in measurement technology which have enabled a broader assessment of physical activity than previously possible. This objective measurement allows the volume and patterns of physical activity at various intensities to be explored, in order to develop a more complete profile of physical activity behaviour that may lead to better health promotion messages. Adults with young children provide an ideal population for physical activity profiling. These adults can experience considerable time constraints and psychosocial influences for participation in purposeful physical activity; however, they are also likely to have distinct sources and patterns of physical activity that have gone undetected in previous studies.

This body of work provides a first step towards a broader understanding of physical activity in adults with and without young children. To start, issues for measuring physical activity in adults with young children were explored (Chapters 3–4); outcomes from these studies highlight substantial limitations to the existing body of knowledge of physical activity in this population. In particular, an overreliance on self-report tools has meant that current knowledge is biased towards MVPA undertaken during leisure-time, and there was an incomplete picture of parental physical activity. These findings provided the basis for development of the subsequent studies to construct a complete profile of parental physical activity, and to investigate whether dimensions of physical activity differed between those with and without young children.

The following three studies explored various dimensions of accelerometer-derived physical activity, in terms of overall amounts (steps and accelerometer counts) at various intensities, hour-by-hour patterns, and patterns of activity accumulation (frequency and duration of bouts at various intensities). A novel approach was used to generate an overall profile of physical activity for those with and without young children, which synthesised the interplay between time spent in sedentary, light, and moderate-to-vigorous intensities (Chapter 6). These studies are the first to investigate physical activity across all intensities in adults with young children and to report objectively-measured sedentary time and light-intensity activity in this population. Overall, adults

with young children spent more time in light-intensity physical activity, and less time in sedentary and MVPA than adults without children. Differences in the overall amount of physical activity (total steps per day) were generally trivial between groups. Hour-by-hour analyses revealed distinct variations in how physical activity was structured through the day between those with and without young children, and minute-by-minute analyses demonstrated that adults with young children accumulated MVPA and sedentary time in shorter bouts than those without young children. A novel and important finding was that adults with and without young children showed distinct profiles of physical activity; those with young children showed patterns of movement throughout the whole day, whereas adults without children displayed distinct periods of high sedentary time offset by periods of MVPA.

The challenge for public health is to acknowledge differences in patterns of living that result in different profiles of physical activity behaviour, and to develop relevant and targeted health promotion messages that lead to sustainable behaviour change. For this to occur, a considerable amount of work is needed to determine more precise dose-response relationships with different amounts, types, and patterns of activity.

# Chapter 1

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## Introduction

### Background

#### Context

Physical activity is an essential component in ensuring optimal health and wellbeing for people of all ages. Being physically active contributes positively to adults' psychological health,<sup>1-4</sup> and there is unequivocal evidence to demonstrate links between regular physical activity and the prevention or management of several major chronic non-communicable diseases for men and women.<sup>5-7</sup> These links place insufficient physical activity among the leading modifiable risk factors of chronic disease and premature death.<sup>8</sup> However, global estimates indicate 31% of the population have insufficient levels of physical activity,<sup>9,10</sup> which is attributed to 6-10% of all deaths from chronic non-communicable diseases worldwide.<sup>6</sup> Despite significant growth in public health efforts to improve physical activity over the last 60 years, rates of insufficient physical activity remain concerningly high.

Life stage has significant consequences for physical activity; however, this factor is often unrecognised in physical activity epidemiology. Parenthood is perhaps the most significant of all life stages, experienced by a majority of adults. In particular, the transition to parenthood brings about a number of meaningful changes to various aspects of an individuals' life and pattern of living which transpire concurrently.<sup>11</sup> At an individual level, biological changes are experienced by women, and changes to employment, finance, and time availability typically occur. At an intrapersonal level, new relationships and responsibilities of care are established, and existing relationships adapt. Socially, a new sphere of social norms and constructions become relevant. In addition, decisions regarding housing and neighbourhoods often occur around this time, and there may be increased participation in healthcare systems. As a result new parents may find themselves having to form new attitudes and beliefs towards physical activity, and negotiate new elements of control over their autonomy for engagement in physical activity.

## **Physical activity in the early parenting years**

Although relatively understudied, the past decade has seen rapid growth in research on the relationship between parenthood and physical activity. Current knowledge indicates that physical activity levels decline during pregnancy<sup>12</sup> through to postpartum,<sup>12</sup> and remain low throughout the postpartum period.<sup>12,13</sup> While a number of studies have shown that mothers are less active than their childless counterparts, evidence is somewhat limited for men. Studies suggest that sources of physical activity may change, with declines in physical activity that is undertaken during leisure time,<sup>14</sup> but increases in household and childcare-related physical activity.<sup>14,15</sup> A growing body of literature has investigated qualitatively the factors that influence physical activity participation, particularly among mothers. These studies highlight significant constraints which are deeply rooted in social constructions of being a 'good mother'.<sup>16,17</sup> Other constraints such as time, lack of energy, parenting responsibilities, and child routines have been documented.<sup>18,19</sup> The benefits of physical activity for adults is indisputable, but additional benefits of a physically active lifestyle for parents extend to the wellbeing of their family unit,<sup>16,20</sup> and to their child's own physical activity behaviour.<sup>21-23</sup> It is imperative that quality research is conducted to improve our knowledge and understanding of physical activity in the early parenting years so that appropriate health promotion messages may be targeted for parents and their families.

In the context of this thesis, the terms 'parent', 'mother', and 'father' refer to a known relationship between adult and child as parent–offspring. For clarification, 'parent' includes biological, foster, step, and adoptive relationships. On their other hand, the term 'with children', as applied to women, men, and adults, refers to those that have children present in the household where the direct relationship is unknown but postulated to be parent–offspring. The terms 'young child' and 'preschool', and their extensions, refer to children aged < 5 years, and are used interchangeably throughout. Further, the terms 'infant' refers to children aged 0–12 months, 'older child' to children aged 5–12 years, and 'dependent' to any child aged ≤18 years, unless stated otherwise.

## **The wider environment**

Over the last 60 years a number of shifts have occurred in physical activity epidemiology in response to evidence and societal changes in lifestyles. Since the 1990s emphasis has been on



the health benefits of regular physical activity of at least moderate-intensity. The early consensus statements on physical activity and health<sup>24-26</sup> were based largely on consensus amongst experts rather than conclusive evidence and formed the basis for public health messages promoting moderate-intensity physical activity on most days of the week. Importantly, these guidelines established a threshold that has been inadvertently applied in subsequent research so that studies investigating the relationship between physical activity and health measured outcomes with respect to attainment of recommended levels of physical activity. This has led to a paucity of knowledge of physical activity that occurs below this moderate-intensity threshold which has been interpreted as absence of an effect, rather than the genuine absence of evidence.

This current situation is a consequence of the difficulties in measuring physical activity. Epidemiological evidence for the relationship between activity and health is predominantly based on self-reported physical activity behaviour and supplemented by evidence from experimental studies for the biological plausibility of these relationships. Self-reports of physical activity are known to be most valid for planned activities at higher intensities,<sup>27</sup> and thus evidence is biased towards these forms of physical activity. Furthermore, lower level light-intensity physical activity, and short bouts of MVPA are not likely to be captured or counted towards overall estimates. However, objective monitoring devices, such as pedometers and accelerometers, have shown completely different ways of capturing daily physical activity in that they capture movement regardless of intensity, duration, or purpose. As a result, a growing number of studies have documented associations between sedentary behaviour and non-communicable diseases<sup>28-31</sup> and all-cause mortality,<sup>32-34</sup> and that light-intensity activity may play an important role in reducing these risks.<sup>30</sup> These results are promising and more research is needed of activity undertaken below the moderate-intensity threshold to fully understand its association with health and wellbeing.

This new evidence has led to an emergence of a new research agenda for physical activity epidemiology—to develop understanding of how different types and amounts of physical activity correspond with health—which will yield a more accurate epidemiology and subsequently better targets for public health. Key to this emerging research agenda is to quantify and investigate overall amounts of physical activity undertaken across the spectrum of intensity, and to examine variations in patterns of these behaviours. Accelerometers offer the best technology at present

for such investigation due to their widespread availability, time-stamped nature of recording, and estimates of intensity via accelerations of movement. Although accelerometers are commonly used in studies of physical activity, the capabilities for analysis of epoch-by-epoch (e.g., minute-by-minute) data across multiple intensities has to date been underutilised. Adults with young children provide an ideal case population for investigation of different types and amounts of physical activity, as this is a life stage where physical activity is likely to have been missed by many of the current public health self-report measures.

## **Thesis rationale**

### **Statement of the problem**

Parenthood is associated with low levels of physical activity; however there are significant gaps in current knowledge of the amounts of physical activity undertaken across the spectrum of physical activity intensity. To date, understanding of the prevalence, trends, and types of physical activity, as well as the factors that influence parental participation and interventions to increase physical activity, have all been based on conventional evidence for levels of MVPA only. As attention turns in the wider field to the neglected contribution of sedentary and light-intensity activity to health and wellbeing, it becomes increasingly clear that parents may be less 'at risk' than previously thought. It is widely believed, although not empirically verified, that parents are 'on-the-go' all the time. Currently however, investigation of such behaviour is lacking and it is possible that parents have distinct patterns of physical activity. There is a critical need to explore the interplay between physical activity intensity, frequency, and duration, as well as the overall volume of activity in order to gather a complete picture of parental physical activity.

A fundamental shortcoming of the current evidence which has led to these significant knowledge gaps is an overreliance on self-report measures of physical activity. Limitations of self-report are widely acknowledged and may be even more prevalent among parents. In particular, unplanned and unstructured physical activities are difficult to recall, with planned vigorous activities the most reliably and accurately recalled. As such, current reports of parental physical activity, and associated correlates, are likely to reflect participation in planned and purposeful behaviour. There is a serious lack of accurate reports of physical activity performed via any means in this population. At the commencement of this thesis, no representative studies

were published with accelerometer-assessed physical activity behaviour of parents; however since this time three studies have been published.<sup>14,15,35,36</sup> While these studies provide much-needed objective reports of MVPA, understanding of lower intensity activity and sedentary time is still lacking. Furthermore, most studies have been carried out in samples of women and there is a paucity of studies on the association between young children and men's physical activity. It is imperative that studies are conducted in men and women with young children that consider the whole spectrum of physical activity.

Research has shown that parents, in particular mothers, face significant and unique constraints to regular participation in physical activity. Social constructions, such as being a 'good mother' and placing others' needs first underpin parents' decisions for physical activity, even before negotiating other significant constraints such as time, energy, childcare, social support, facilities, and cost. These deeply-rooted beliefs and constraints are not easily negotiated and require targeted behavioural approaches. However, studies have continued to focus attention on strategies to negotiate these constraints rather than consider opportunities for physical activity that occur within the parameters of parenthood. By understanding the amounts of physical activity, and the patterns of behaviour, it may instead be possible to identify opportunities to accumulate and achieve higher levels of physical activity within the parameters of parenthood.

What is more, the full potential of understanding physical activity from accelerometer data is yet to be realised. So far most studies have aggregated accelerometer data to estimates of daily or weekly physical activity, or average counts per epoch. Novel methods of analysis are emerging,<sup>37-39</sup> however few studies have applied such techniques to general populations. This will be the first study to apply a battery of novel approaches to analysing accelerometer data in order to provide a full profile of physical activity amounts, intensities, and patterns. These novel forms of accelerometer data treatment will lead to better understanding of physical activity patterns and intensities accumulated across the activity spectrum.

## Statement of the purpose

The overarching aim of this research was to investigate the amounts and ways in which adults with and without young children accumulate physical activity across the full activity intensity spectrum. A secondary aim was to explore methods of analysing accelerometer data to provide useful descriptions of physical activity patterns. The specific objectives of this research were to:

1. Review and critique existing research that has examined physical activity behaviour in adults with young children, with reference to the wider epidemiological field (Chapter 1).
2. Determine the appropriate method for quantifying physical activity in adults with young children by undertaking the following approaches:
  - a. Systematically review and critique physical activity measurement methodology employed in previous research of women with young children (Chapter 2).
  - b. Investigate the validity of using self-report to quantify physical activity behaviour in men and women with young children (Chapter 3).
3. Quantify and describe physical activity behaviour and patterns in a cross-section of adults with and without young children residing in New Zealand by completing the following:
  - a. Quantify and investigate differences between the distribution of physical activity intensity of adults with and adults without young children (Chapter 4).
  - b. Identify and describe the patterns of physical activity of adults with and without young children using time-stamped accelerometer data (Chapters 5 and 6).
  - c. Investigate differences between the patterns of physical activity of adults with and without young children (Chapters 5 and 6).
4. Implement novel approaches to interpreting time-stamped accelerometer data to generate a broad profile of the totality of physical activity in adults with and without young children.

## **Significance of the research**

The series of studies that follows contains several novel contributions to the body of literature both for physical activity in parents and wider epidemiology.

A large proportion of the population become parents at some stage during their adult life, and the subsequent changes to their pattern of living may have significant implications for their physical activity habits. Not only is physical activity important for parents' own health and wellbeing, but parents are also central agents for opportunities, support, and encouragement for their young children to be physically active. Current knowledge indicates that parents engage in less planned and purposeful physical activity due to substantial structural and ideological constraints. However, little is known of the opportunities for physical activity that occur through their everyday patterns of living. This research provides the first investigation of parental physical activity across all levels of intensity through accelerometer assessment of physical activity, including much needed evidence of time spent sedentary. Furthermore, this research makes a significant contribution to the body of knowledge on the patterns of parental physical activity, providing greater understanding of how adults with young children move throughout the day, which can lead to better targeted health promotion messages.

The methods employed in this study for analysis of accelerometer data also make a significant contribution to the wider field for measuring physical activity. Accelerometers are widely used through epidemiology, however their full potential has to date been underutilised. This study employed novel approaches to interpret accelerometer data to generate a total profile of physical activity, including the overall amount of physical activity at all intensities, patterns of the totality of physical activity throughout the day, and patterns of physical activity and sedentary accumulation. Greater understanding of the nuances of physical activity behaviour and its relation with health and wellbeing is important for moving the field forward, and this novel approach to accelerometer treatment is a first step in this process.

The outcomes of this body of work also provides a significant contribution to the wider epidemiological field by developing understanding of different profiles of physical activity behaviour. For epidemiology and public health to move forward and make substantial change to non-communicable disease and rates of physical activity, attention needs to move away from a one-size-fits-all approach to health promotion. Greater understanding of different profiles of physical activity behaviour, and individual responses to physical activity is crucial for more

effective and targeted health promotion messages that take into account the context of everyday living. The outcomes of this thesis provide an important case-comparison for how physical activity may be accumulated in ways that are different from the traditional MVPA during leisure-time paradigm.

## **Study delimitations**

Parameters specific to this body of work are as follows:

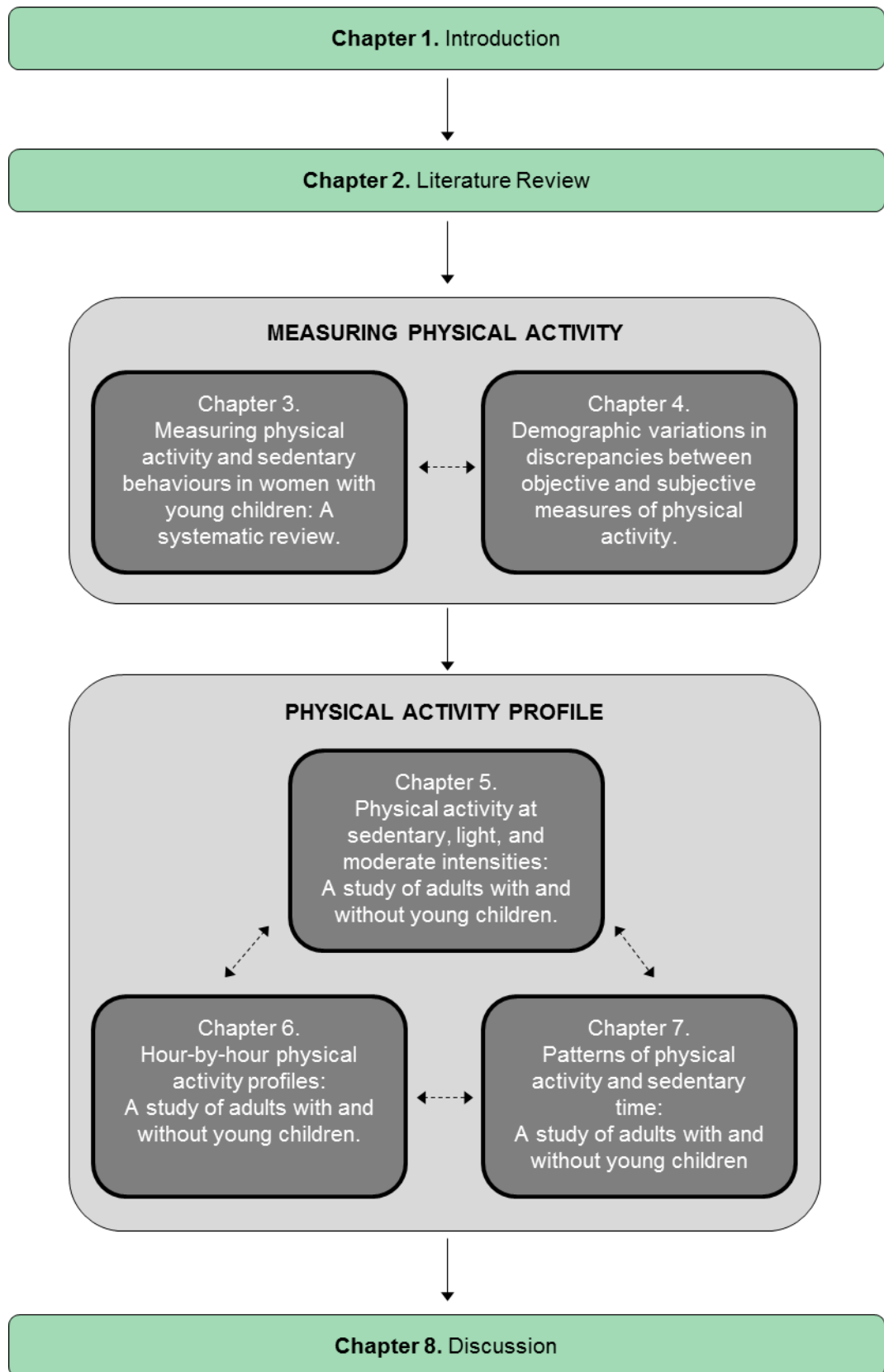
1. The overall aim of this research was to explore physical activity behaviours of adults with young children. The wider study from which data was derived provided information on the occupants of the household, including children aged < 18 years. Participants were assigned to sub-groups based upon this information, with prioritisation used to determine classification of those with both young and older children. Participants living with any occupant aged < 5 years were classified as 'adult with young child', remaining participants living with occupants aged 5–12 years were classified as 'adult with older child', and participants with no occupants in the household aged < 13 years were classified as 'adult with no child'. As such, the effects in this study specifically relate to effects of having a child reside in the household rather than the effects of parenthood per se.
2. The data collected were cross-sectional and therefore no causality can be inferred.
3. Accelerometers were hip-mounted and provide valid estimates of ambulatory movement, however upper body movements, load carriage (e.g., carrying a child), and posture (e.g., sitting) could not be assessed.
4. Accelerometer-assessed physical activity does not provide descriptive data on the type of activity or the context in which it occurred.
5. Accelerometer models and data treatment vary widely across studies thus cross-study comparisons are difficult. The estimates of physical activity derived in these studies may not be directly comparable with other studies employing different models or data treatment procedures.

6. Chapter 3 consists of a literature review published in a relevant peer-review journal in 2011. Accordingly, relevant articles published after acceptance of this review have not been included in this chapter, however, where appropriate, more recent literature has been added to the following empirical chapters.
7. The statistical approach used throughout Chapters 5–7 is based on inferential statistics that emphasise precision of estimation rather than the more traditional null hypothesis testing. Rather than using statistical significance and P-values to make inferences about true values of effects, this approach uses magnitude-based inferences based on probabilities,<sup>40</sup> and is likely to be a more realistic or intuitive way of deducing outcomes. Inferences are based on where the confidence interval lies in relation to thresholds for substantial effects rather than the null value, and are referred to as non-clinical effects. If the confidence interval overlaps substantial positive and negative values, the effect is described as being unclear. Clear effects are reported as positive, negative, or trivial, depending on the observed value on the effect. Confidence limits for non-clinical effects were at 90% certainty. Effects that were clear at the more conservative 99% confidence interval were also indicated. The magnitude of a given clear effect was determined from its observed standardised value (the difference in means divided by the between-subject standard deviation) using the following scale: <0.20, trivial; 0.20–0.59, small; 0.60–1.19 moderate; and  $\geq 1.20$ , large. More detail on this approach is provided by Hopkins et al.<sup>40</sup>

## **Thesis overview**

### **Thesis organisation**

This thesis is presented as a sequential progression of studies arranged in a series of chapters. Chapter 2 provides the research context within physical activity epidemiology and a review of the current knowledge in parents of young children. The body of the thesis contains five chapters arranged in two parts (Figure 1). The first part consists of two chapters which examine measurement of physical activity in parents of young children (Chapters 3 and 4). Chapter 3 provides a systematic review of the measurement of physical activity in previous studies of women with young children and identifies considerable knowledge gaps. Chapter 4 examines



**Figure 1.** Thesis Structure

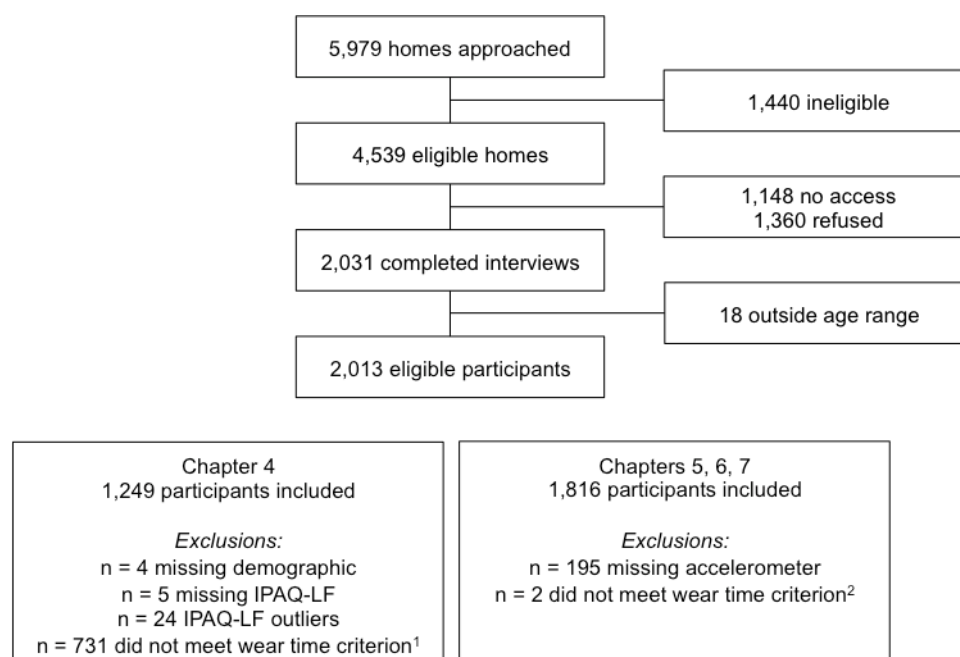


the utility of self-report and accelerometer measures of physical activity in men and women with and without young children. Findings from the first part determined the choice of physical activity measure for analysis in the second part, consisting of three chapters which represent the primary investigation of amounts and patterns of physical activity in adults with and without young children. Specifically, Chapter 5 investigates the overall amounts of physical activity across the full spectrum of intensity. Chapters 6 and 7 examine patterns of physical activity, including hour-by-hour profiling and bouts of activity. Chapters 3 to 7 have been prepared as separate papers for publication in peer-reviewed journals; therefore some repetition of information occurs. The prefaces serve to link the chapters and outline the logical progression of studies as a cohesive whole. The purpose of the final chapter (Chapter 8) is to bring together the findings and recommendations that emerged from this research, and the implications of these in the research and wider communities while noting the limitations of the research. Supplementary information not provided in the thesis chapters (supplementary data and published papers) has been included as Appendices.

## **Thesis methodology**

Chapters 3 to 7 of this thesis analyse data from a collaborative multi-university cross-sectional study (Understanding Relationships Between Activity and Neighbourhoods [URBAN]) participating in a wider international research group (International Physical Activity and the Environment Network; IPEN). Full details of the URBAN Study research design and methodology are presented in Appendix A. An overview of the study methodology and flow of participant recruitment pertaining to this thesis is outlined forthwith.

The URBAN study is a multi-centre, stratified, cross-sectional study of associations between physical activity, health and the built environment in adults and children residing in New Zealand. The study was conceptualised using a social-ecological framework, with the levels being: country, city, neighbourhood, household, and individual. Participants were recruited between April 2008 and September 2010 from 48 neighbourhoods across four New Zealand cities that were stratified by high—low walkability and high—low Māori population. A total of 2,013 eligible adults were recruited into the study with a response rate of 45%; Figure 2 demonstrates the flow of participant recruitment and inclusion in analyses for subsequent chapters.



**Figure 2.** Overview of participant recruitment. Final response rate 45%; <sup>1</sup>Wear time criterion:  $\geq 5$  days and  $\geq 10$  h per day; <sup>2</sup>Wear time criterion:  $\geq 1$  day and  $\geq 6$  h per day.

On the recruitment visit, trained interviewers gained written informed consent and delivered accelerometers and travel logs. Eight days later, the interviewer returned to the participants' home to collect the accelerometer and travel log, and measure participants' height, weight, and waist and hip circumferences. Participants also completed a 40 min computer-assisted personal interview with a trained interviewer that assessed individual and household demographics, neighbourhood perceptions and preferences, physical activities, and sedentary behaviours.

A range of measures were employed in the URBAN study that were in accordance with the wider international study (IPEN Study) protocols. Measures specific to this thesis include physical activity measured via accelerometer and self-report, and demographic variables. Hip-mounted Actical accelerometers (Mini-Mitter, Sunriver, OR) were used to objectively measure participants' physical activity across seven consecutive days and the International Physical Activity Questionnaire in long form (IPAQ-LF) was administered via interview to capture adults' self-reported physical activity for the previous seven days. Adults reported details on household composition, included the ages of all children aged  $< 18$  years residing in the dwelling. Specific details pertaining to the treatment of data vary somewhat between chapters and are thus described in detail in the methods section of each chapter.

## **Candidate contributions**

The thesis fulfils the terms of an Auckland University of Technology Doctoral degree through a significant, original contribution to knowledge in physical activity among adults with young children via critical appraisal of the existing literature and empirical studies.

The formation and development of the research questions were undertaken solely by the candidate. In the first instance, these research questions were formed in response to disconnect between personal observations of the population of interest and the evidence in the literature. These research questions were further developed following a systematic review of the literature which identified a significant knowledge gap, and continued to evolve in response to findings from the data. The decision to utilise data from the URBAN study was based on the study's robust research design, large sample size and measurement of physical activity via self-report and accelerometer, which enabled a thesis of superior quality than could have been achieved under normal doctoral resources.

While this thesis analyses data from a larger collaborative study the candidate made a substantial contribution to this study. The data collected for the URBAN study was under contract with a data collection agency. During the data collection phase, the doctoral candidate was a key member of the project team and was responsible for coordinating the weekly receipt of data from the data collection agency (including survey, accelerometer, and travel log data) and subsequent management of the dataset. In addition, the candidate sourced daily weather data from the national weather stations and coded participants' home, school and workplace addresses. Once data collection was completed, the candidate spent 6 months cleaning and scoring the data prior to its release to the wider project team and international collaborative partners. Furthermore, the candidate continued responsibility for the on-going management and coordination of the dataset with the collaborative project team, and international partners.

Analysis of data for this thesis was initiated, planned, and undertaken independently from the wider study. Through the process of independent work, the ensuing chapters demonstrate well-developed skills of research, critical analysis, and application. In addition, the doctoral candidate has been involved in on-going international academic discussion of parental physical activity

through dissemination of research findings to the international academic community in the form of peer-reviewed presentations and journal articles.

### **Research chapter contributions**

Chapters 3–7 of this thesis are comprised of scientific papers that are published (or in preparation for submission) in international peer-reviewed journals. The academic contributions and specific role of the doctoral candidate for these research chapters were as follows:

Chapter 3: Measuring physical activity and sedentary behaviours in women with young children: A systematic review.

Lisa Mackay .....80%

Grant Schofield.....10%

Melody Oliver .....10%

Chapter 4: Demographic variations in discrepancies between objective and subjective measures of physical activity.

Lisa Mackay .....90%

Grant Schofield.....5%

Melody Oliver .....5%

Chapter 5: Physical activity at sedentary, light, and moderate-to-vigorous intensities: A study of adults with and without young children.

Lisa Mackay .....70%

Grant Schofield.....10%

Melody Oliver .....10%

Will Hopkins.....10%

Chapter 6: Hour-by-hour physical activity profiles: A study of adults with and without young children.

Lisa Mackay .....90%

Grant Schofield.....5%

Melody Oliver .....5%

Chapter 7: Patterns of physical activity and sedentary time: A study of adults with and without young children.

Lisa Mackay .....85%

Grant Schofield.....5%

Melody Oliver .....5%

Will Hopkins.....5%

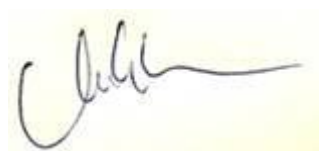
**Co-author agreement**



Professor Grant Schofield



Dr Melody Oliver



Professor Will Hopkins

## Chapter 2

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### Literature Review

#### Preface

Parents of young children are a population group that have consistently been shown to have low levels of physical activity. However, emergent perspectives in physical activity epidemiology call for a broader understanding of physical activity behaviours across the full intensity spectrum. This new perspective has emerged in light of new insights of sedentary behaviour and is in response to continued global trends for prevalent non-communicable disease and low population levels of physical activity. Parents of young children may be a population group for which an incomplete picture of physical activity has so far been presented. Some authors have posited that parents accumulate substantial physical activity that has gone undetected by traditional measures of physical activity. Time use studies also provide support for this hypothesis, with higher levels of household and childcare related time among parents than non-parents. As such, it is worthwhile to examine the physical activity behaviours of parents from this emergent perspective. The purpose of this review is two-fold: 1) to demonstrate the development of an emergent perspective on physical activity and the rationale for adopting this perspective; and 2) to review the current state of knowledge of physical activity in adults with young children.

## **Physical activity epidemiology**

Non-communicable diseases are the leading cause of death globally, accounting for 63% of all deaths, and are projected to continue to rise.<sup>41</sup> A large percentage of these diseases, which include cardiovascular diseases, type 2 diabetes, cancers, and chronic respiratory diseases, are largely attributed to unhealthy lifestyle factors including insufficient physical activity. While physical activity was previously a concomitant behaviour of daily living, the last century has seen immense changes to the urban environment and advances in technologies which have resulted in increasingly sedentary lifestyles. To compensate, opportunities for physical activity need to be created in order to achieve the levels required for optimal health and prevention of disease.

Adults are recommended to undertake at least 150 min of moderate-intensity aerobic physical activity throughout the week, or at least 75 min of vigorous-intensity aerobic physical activity, or an equivalent combination of the two.<sup>42</sup> However, global estimates indicate 31% of adults did not achieve these guidelines in 2008.<sup>9,10</sup> New Zealand is no exception from this worldwide problem with 48% of adults not attaining recommended levels, behind the United States (41%), Australia (38%), and Canada (34%).<sup>10,43</sup> The global burden of this problem is evident with insufficient levels of physical activity attributed to 6–10% of all deaths from the major non-communicable diseases (coronary heart disease, type 2 diabetes, and breast and colon cancers), and 13% of such deaths in New Zealand.<sup>6</sup>

The value of human movement for health and wellbeing has been widely acknowledged throughout history; however definitions of physical activity and recommendations for the dose required for health have changed over time in response to advancements in measurement and evidence. In order to understand the current position of physical activity epidemiology it is helpful to consider the events and evidence that have shaped this position.

### **Traditional perspectives**

The early beginnings of physical activity epidemiology originated from the influence of two distinct fields of study. The first consisted of epidemiologists who observed patterns in disease among populations and began to apply this approach to non-communicable disease, in particular coronary heart disease. The second field consisted of physicians and physical

educators who conducted experiments on the physiological effects of exercise and training for health and athletic performance. Although these fields of study had different methodologies and lines of enquiry, they were united in their objective to understand what makes people healthy.

#### From occupation to leisure

The link between physical activity and non-communicable disease was first established in the mid-1950s. Epidemiologist Professor Jeremy Morris studied the associations between occupation and incidence of coronary heart disease among London bus drivers and conductors and determined that men in physically active jobs suffered less from coronary heart disease and related mortality than those in sedentary jobs.<sup>44</sup> The theory resulting from this study was that physically active work provided a protective effect against coronary heart disease.<sup>44</sup> This novel outcome was confirmed in subsequent studies of occupationally active versus sedentary postal workers and rail workers in both Britain and the United States.<sup>44,45</sup> Around this time immense changes to the occupational environment were occurring with widespread adoption of advanced technology which resulted in a reduction of heavy labour occupations and an increase in office-based jobs. As such, epidemiological research efforts shifted to understand physical activity undertaken during leisure time in an attempt to combat the increasingly sedentary lifestyles of the working population.<sup>46</sup>

#### Vigorous exercise during leisure

During these formative years of physical activity epidemiology, there were two hypotheses for the relationship between physical activity and coronary heart disease: 1) that overall energy expenditure was inversely related to disease incidence, or 2) that high-intensity activity that produces a training effect lowered disease incidence.<sup>47</sup> These hypotheses were investigated in a study of 16,882 male office workers who completed an activity recall of 5 min intervals across two days.<sup>47</sup> Results from this study showed that those who reported doing vigorous activities during non-work hours (including recreational exercise and heavy yard work) had the lowest relative risk of developing coronary heart disease. Participation in moderate exercise without additional vigorous exercise, showed no effect and analysis of the amount of moderate activity was unclear.<sup>47</sup> Similar results were seen in other studies<sup>48,49</sup> and thus subsequent attention focused on leisure-time vigorous physical activity that increased cardiorespiratory fitness.



## Vigorous exercise to moderate physical activity

During the 1970s and 1980s, epidemiological studies and exercise science experimental studies continued to develop links between exercise, fitness, and health. By the end of the 1980s there was significant growth in the number of studies; the first international consensus group was formed to review the evidence, and a consensus statement was released on exercise, fitness, and health.<sup>24</sup> This statement concluded that physical activity and fitness were key determinants of health, however more research was needed to understand the relationships more fully. In 1993 this consensus statement was updated and expanded to include developments in understanding of a range of health benefits from more moderate levels of activity intensity.<sup>25,50</sup> In particular, evidence was most clear for a graded inverse relationship between physical activity, fitness, and coronary heart disease, with reduced risk even at more moderate levels of activity. Evidence for the effects of exercise on other health indicators, including insulin sensitivity, blood pressure, bone density, and obesity was emergent, however epidemiological evidence was scarce.

In 1995, the first public health-oriented physical activity guideline was issued in a joint statement by the prominent epidemiological and exercise science organisations, the Centers for Disease Control and Prevention (CDC, established 1946) and the American College of Sports Medicine (ACSM, established 1954), respectively. This statement recommended that every adult should accumulate 30 min or more of moderate-intensity physical activity on most, preferably all, days of the week.<sup>51</sup> Although fitness and exercise recommendations had been issued previously by the ACSM<sup>52</sup> this was the first statement aimed at improving the health of the population.

In the early 1990s several government agencies began to acknowledge the importance of physical activity for public health, and the U.S. Office of the Surgeon General commissioned a report on physical activity to summarise the existing evidence for the association between physical activity and prevention of non-communicable disease.<sup>26</sup> This comprehensive review concluded that regular physical activity of at least moderate intensity reduced the risk of coronary heart disease, type 2 diabetes, hypertension, and colon cancer, and produced beneficial effects for mental health and healthy bones, muscles, and joints. There was consensus that physical activity should be regular, that benefits could be gained from moderate-intensity activity, and that greater health benefits could be gained from more vigorous intensity

physical activity. This landmark report marked a significant shift in physical activity epidemiology with a new emphasis on the range of health outcomes achieved through regular moderate-intensity physical activity.

#### Strengthened moderate physical activity evidence

Following the release of the U.S Surgeon General's report in 1996 there was a proliferation of epidemiological and physiological studies of physical activity, including its relation with health, developments in measurement technology, understanding of determinants, and evaluations of interventions. Studies were conducted in a wide range of settings and populations, including children, women, adults, older adults, ethnic groups, and low-income groups. Associations between moderate-intensity physical activity and health were confirmed in a number of sub-populations. In 2000, an international group of health experts reviewed developments in evidence for physical activity and health with a view to producing an updated consensus statement on the amount and type of physical activity required for health benefit.<sup>53</sup> This consensus statement concluded that regular physical activity was associated with a number of major health benefits and determined an inverse and generally linear dose-response relationship of self-reported physical activity with all-cause mortality, cardiovascular disease and mortality, and incidence of type 2 diabetes.

In 2010, an updated review of the evidence informing current physical activity guidelines was published which confirmed earlier links between insufficient physical activity and death or disability from major non-communicable diseases, including coronary heart disease, colon cancer, breast cancer, and type 2 diabetes.<sup>5</sup> The authors concluded that current recommended levels of physical activity are sufficient to reduce the risk for non-communicable diseases, but also a linear dose-response relationship exists where further health benefits may be achieved with increasing levels of physical activity. Most recently, in 2012, a physical activity series was published in *The Lancet* which reviewed evidence and presented an update on the trends of physical inactivity and current knowledge on the relationship between physical activity and health.<sup>6,10,54-57</sup>

## ***Reflections***

It is evident that a number of significant shifts in perspective of what type of physical activity is important for health have occurred in response to advances in evidence and societal megatrends. To begin, the first documented links were between physically active occupations and coronary heart disease risk and mortality. In response to changes in the occupational environment, research shifted to leisure-time physical activity and the protective effect of vigorous-intensity activities for coronary heart disease was documented. As more research was undertaken in wider populations, it became evident that a graded dose-response relationship existed between physical activity and health, where benefits to health were observed from modest levels of physical activity and greater benefits could be achieved from higher levels. However, the early consensus statements in 1990 and 1993, and the 1995 ACSM/CDC recommendations relied largely on consensus opinion of experts in the field rather than conclusive evidence from randomised clinical trials.

On reflection, the introduction of public health recommendations for the level of physical activity required for health benefit established a threshold that was applied in subsequent research. Following the release of the U.S. Surgeon General's report, many of the studies investigating the relationship between physical activity and health measured health risk with respect to attainment of recommended levels of physical activity; those who did not attain this level were classified as 'sedentary' or 'inactive'. This has led to a lack of knowledge on the amounts and type of physical activity performed below this threshold, and any health benefit that may be incurred through such activity. Not to discount the clear links between regular physical activity of moderate-to-vigorous intensity and health, the limited evidence for links between lower intensity physical activity and health is due to an absence of evidence rather than absence of an effect.

The absence of evidence is also in part due to the sensitivity of physical activity measurement tools to capture lower intensity activity. The majority of epidemiological studies have employed self-report methods of assessing physical activity levels, due to their low-cost and ease of use. The key limitation of these methods is their limited accuracy for measuring unstructured and lower intensity physical activity; structured physical activity at vigorous intensities are the most accurately recalled.<sup>27,58</sup> As such, the established links with health are thus predominantly related to levels of MVPA, which in turn inform public health recommendations.

### ***Trends in physical activity***

National and international surveillance of physical activity levels has occurred only relatively recently, as such historical trend data is limited. However, in the United States, the Behavioural Risk Factor Surveillance System first included assessment of exercise activities in 1984.<sup>59</sup> Temporal trends from these data indicate that since the 1980s there have been marginal increases in MVPA in the United States.<sup>60</sup> Similarly, a systematic review of physical activity trends concluded that adults' leisure-time physical activity tend to be increasing (studies were from United States, Canada, Europe, Asia and Oceania).<sup>61</sup>

Trend data of non-leisure physical activity are scarce, however Brownson et al.<sup>60</sup> documented evidence from labour, census, and transportation statistics to provide an indication of non-leisure physical activity trends. These authors showed that rates of highly active occupations have declined since the 1950s and rates of low active occupations have increased. Similarly, they presented a clear upward trend in the ownership and use of private motor vehicles with a corresponding reduction in trips by active modes (i.e., walking and cycling). The authors concluded that these trends show widespread decline in physical activity accumulated via activities of daily living and fairly stable, but low, participation rates in leisure-time physical activity.<sup>60</sup> These conclusions have also been supported by other studies on physical activity trends.<sup>61-63</sup>

### **Modern perspectives**

Similar to earlier shifts in focus from occupation to leisure-time physical activity, and from vigorous exercise to activity of moderate intensity, another shift has occurred in recent years. In response to emergent evidence that sedentary behaviour is associated with a number of poor health outcomes, independent of physical activity levels, attention is shifting towards a broader view of physical activity and health. Although studies remain few, sedentary time has been associated with risk for all-cause mortality,<sup>32-34</sup> cardiovascular disease,<sup>28</sup> some cancers,<sup>64,65</sup> and metabolic syndrome,<sup>29-31</sup> independent of MVPA levels. The way in which sedentary behaviour is accumulated, in particular the frequency of interruptions, has also been independently linked with metabolic health outcomes.<sup>31,66</sup> Studies have shown that those who regularly break up their sedentary time have a more favourable metabolic risk profile than those who accumulate prolonged bouts of sedentary time.<sup>31,66</sup> Less understood are the health effects of light-intensity

physical activity (i.e., 1.5–2.9 METs). However, emerging research indicates a negative association between light-intensity physical activity and risk for all-cause mortality,<sup>67</sup> metabolic risk,<sup>30,68</sup> and weight gain.<sup>69</sup> Evidence is continuing to mount in support of a shift in physical activity epidemiology to understand the complete range of physical activity intensities.

Of particular importance is the growing evidence to support that sedentary behaviour is a risk factor for non-communicable diseases independent of physical activity levels. This evidence shows that even among adults who achieve physical activity recommendations, high levels of sedentary behaviour are associated with a range of poor health indicators.<sup>28,30,32,34,64,70</sup> A seminal article by Hamilton and colleagues<sup>71</sup> proposed that the physiological responses to sedentary behaviour and physical activity are different and thus influence health in different ways. The authors presented evidence from studies to show that prolonged periods of sedentariness initiate cellular processes different from exercise responses, particularly cellular regulation of skeletal muscle lipoprotein lipase (LPL). These processes can result in reduced insulin sensitivity and altered lipid metabolism, both of which are key metabolic risk factors.<sup>71</sup> At this point relatively little is known of the full physiological and molecular responses to sedentariness, but the emergent research supports epidemiological evidence for the independent associations of sedentary time and MVPA with health.

A number of key researchers in the field of physical activity epidemiology have put forth arguments that a new perspective on physical activity is needed. In 2009, notable Australian researchers Brown, Bauman and Owen<sup>72</sup> discussed a paradigm shift towards a balance of physical activity and sedentary behaviour across all aspects of daily life. They argued that in the context of increasingly sedentary lifestyles, leisure-time physical activity would not be sufficient for prevention of non-communicable diseases, overweight and obesity. These arguments have been echoed and expanded by other researchers (see Powell et al.<sup>73</sup> Hamilton et al.<sup>74</sup> Bauman et al.<sup>63</sup> Hallal and Ekelund,<sup>75</sup> Katzmarzyk,<sup>76</sup> Marshall and Ramirez,<sup>77</sup> and Owen et al.<sup>78</sup>). Some of the key messages from these arguments are that: a whole-of-physical activity approach is needed with more understanding of physical activity that occurs in the 'background' of daily life; leisure-time physical activity alone is not enough to combat increasingly sedentary lifestyles; and substantial benefits could be seen for population health if sedentary behaviours were replaced with light-intensity activity.

The whole-of-physical activity approach requires an equal balance of attention given to sedentary, light, moderate, and vigorous intensities of physical activity. It has been argued that the specificity principle of exercise science is applicable, whereby different types of physical activity may influence a diverse range of health outcomes via multiple physiologic pathways.<sup>71,73,79</sup> Previously, the application of a minimum threshold (i.e., moderate-intensity) for health benefit has resulted in a severe lack of knowledge of the substantial variation in 'background' physical activity that occurs below this threshold.<sup>73</sup> This is mainly due to difficulties in measuring such activity, however application of accelerometers to objectively collect physical activity time-series data allow activity across the full spectrum of intensity to be examined.

The most recent public health recommendations for physical activity remain largely unchanged from those prescribed in 1995,<sup>51</sup> that adults should accumulate at least 150 min of moderate-intensity physical activity throughout the week.<sup>42</sup> In 2007, clarifications were made for previously ambiguous guidelines:<sup>80</sup> bouts of moderate-to-vigorous intensity aerobic physical activity should be of at least 10 min duration and in addition to the frequent and routine activities of daily living. It is clear from these clarifications that the recommended guidelines relate to undertaking purposeful physical activity. However there remains ambiguity over the level of 'routine activities of daily living' that is required as a baseline.<sup>73</sup> It has been argued that the greatest declines in physical activity over the last 60 years has occurred through these activities, rather than leisure-time activity.<sup>60,62</sup> In light of the growing evidence for the importance of balancing sedentary behaviour and physical activity there have been calls for a message that encompasses the whole-of-physical activity approach: to sit less, move more (light-intensity activity), and exercise.<sup>63,74,81</sup> It is important, however, to note that this new modern perspective is in addition to the substantial and well-recognised benefits of MVPA, rather than an alternative message.<sup>74</sup>

### ***Looking ahead***

In their commentary of developments in physical activity epidemiology, Hallal and Ekelund<sup>75</sup> described how past improvements in scientific knowledge has led to an evolution of physical activity perspectives and public health messages, and they proposed that developments in measurement technologies would "generate new knowledge, challenge our current beliefs, and change our way of thinking" (p.569). One of the fundamental reasons for the emergence of knowledge of sedentary and light-intensity activity is the relatively recent ability to quantify the

amounts and patterns of these activities in large population studies through the use of motion sensors.

Previously, the cost of motion sensors prohibited use in large scale studies, but as improvements were made in their accuracy and costs reduced, motion sensors began to be more widely adopted. Motion sensors capture movement associated with physical activity, typically ambulatory activity, and include pedometers, accelerometers, and inclinometers. These devices can provide an objective assessment of the accumulation of movement regardless of intensity, duration, or purpose. Initially, pedometers were the most popular motion sensor however accelerometers are now widely employed in both small and large-scale studies. Of note, accelerometers were first employed in the U.S. National Health and Nutrition Examination Survey surveillance program in 2003.

Typically hip-mounted, most accelerometry-based devices register acceleration through piezoelectricity and record detailed temporal data in terms of 'activity counts' per epoch (typically  $\leq 1$  min). Activity counts are the raw digital signal output proportional to the applied acceleration of movement.<sup>82</sup> Validated algorithms are applied to activity counts to predict energy expenditure; each epoch is thus classified as sedentary, light, moderate, or vigorous intensity. The resulting output for each epoch includes the raw activity counts, and estimated energy expenditure and intensity. Measurements may be taken over a continuous period of up to 45 days, depending on the device and settings applied. A number of commercially developed accelerometers have been validated against energy expenditure from indirect calorimetry and oxygen uptake ( $\text{VO}_2$ ), and are suitable for use in large-scale field research. Accelerometers are popular in field-research of free-living participants as they provide objective time-stamped data on movement with estimates of intensity that allow frequency and duration of physical activity to be established. Accelerometer data also enable estimation of time spent sedentary by identifying periods with very low—or no—activity counts. However, the complexity of these devices present many technical decisions that must be made (i.e., devices settings, data reduction) which have an indeterminate effect on the resulting data for analysis; presently there is little consensus on the rules of such decisions.<sup>83,84</sup>

With reference to modern perspectives, accelerometers have some distinct advantages. Firstly, these motion sensors record movements regardless of intensity or duration, and thus are able to

capture a broad spectrum of physical activity. Furthermore, time-stamped data allows patterning of physical activity, at various intensities, throughout the day to be examined. However, to date the full functionality of accelerometers, in terms of interpreting data, has not been widely utilised. So far, studies have used three primary approaches for investigating patterns: duration of sedentary and MVPA bouts, frequency of interruptions in sedentary time, and hour-by-hour patterns of physical activity.

In order to aid comparability of accelerometer-derived physical activity with recommended levels of physical activity, a number of studies have examined accelerometer-derived MVPA that is accumulated in bouts of at  $\geq 10$  min durations. Generally these studies identify contiguous min of MVPA, with an allowance of 1–2 min break at another intensity (i.e., sedentary or light) for every 10 min of MVPA. While this method is useful for identifying bouts of sustained MVPA, comparison with recommended levels of physical activity is inappropriate as they are based on different methodologies.<sup>85</sup> Recommended levels of physical activity have been informed by studies documenting links between self-reported physical activity and health. Such self-report estimates of physical activity are likely to be related to duration of the activity rather than duration of a specific intensity. For example, playing a game of tennis may be self-reported as a 30 min period of MVPA, however in reality this period would involve regular stoppages that would result in physical activity below the moderate-intensity threshold. However, the sensitivity of accelerometers to assess minute-by-minute physical activity would be unlikely to classify this same activity as a 30 min bout of MVPA, even with an allowance of 1–2 min break per 10 min of MVPA. Other continuous aerobic activities, such as brisk walking or running might yield more accurate assessments. Nevertheless, further research on patterns of accelerometer-derived MVPA bouts is needed to provide insights into optimal patterns of physical activity for health.

Increasingly, similar methods have been applied to assessment of sedentary time, in particular the duration of sedentary bouts and frequency of breaks in sedentary time. The first study to explore such patterns was published in 2008 (N = 168 adults); Healy et al.<sup>66</sup> explored patterns in accumulation of sedentary time by investigating the total number of breaks in sedentary time. Breaks in sedentary time were identified as transitions from  $\geq 1$  min of sedentary time to  $\geq 1$  min above the sedentary threshold. This study found that the pattern of accumulating sedentary time was associated with metabolic risk factors, in particular the frequency of breaks in sedentary



time. A number of studies have replicated similar methods for investigating the association between patterns of sedentary time and health.<sup>28,31,86</sup>

Only a few studies have explored hour-by-hour patterns of physical activity. Two studies explored hourly patterns of moderate-intensity physical activity in adult populations by weight status (N = 84 adults) (N = 2,253)<sup>87</sup> and neighbourhood type.<sup>88</sup> Another study explored hour-by-hour patterns of sedentary time, light-intensity activity, and MVPA in work and home contexts among employed adults (N = 193).<sup>89</sup> Also, a study of preschool children examined hour-by-hour patterns of sedentary time and MVPA in boys and girls aged 3–6 years (N = 703).<sup>90</sup> These studies describe when physical activity is accumulated and provide insights into whether activity is performed throughout the day or in distinct periods. This is important for two reasons: first, it highlights periods of high and low physical activity, and high and low sedentary time, which may be targeted in behaviour change interventions; secondly, it allows more in-depth investigation into the relationship of accumulated versus episodic physical activity with health outcomes that will further add to understanding of optimal patterns of physical activity for health.

In 2007, Esliger and Tremblay<sup>85</sup> explored the opportunities for detailed activity profiles from accelerometers using a case-study approach. They proposed that physical activity profiles could be described by intensity, patterns of accumulation, and time of day. More recently, Thompson and Batterham<sup>39</sup> presented a comprehensive approach to profiling the totality of physical activity from sedentary, light, moderate, and vigorous intensities. The authors argued that while some dimensions of physical activity are correlated, it is possible to do well on one and poorly on another. Consequently, they proposed ways to capture combinations of physical activity dimensions into an overall profile. Their approach was based on individualised feedback of attainment of various physical activity thresholds, as such the activity profile represents whether or not a participant attained a threshold of five physical activity dimensions: physical activity level (total energy expenditure/resting energy expenditure);  $\geq 150$  min MVPA or  $\geq 75$  min VPA, per week (accumulated in bouts of  $\geq 10$  min);  $\geq 60$  min MVPA per day (accumulated on minute-to-minute basis);  $\geq 25$  min VPA on  $\geq 3$  days per week (accumulated in bouts of  $\geq 10$  min); and  $< 60\%$  of waking hours in activities  $< 1.5$  METs.

These various approaches provide a useful starting place to investigate the totality of physical activity. Breaks in sedentary time and MVPA accumulated in bouts of  $\geq 10$  min are the most

widely adopted approaches. Future research should employ a battery of techniques to generate a complete profile physical activity in various populations, such as the overall amounts, daily structure, and patterns of accumulation.

## Concepts and definitions

Physical activity is a complex, multi-dimensional behaviour. Since the mid-1950s the concepts and definitions of physical activity and its related constructs have evolved. It is relevant at this point to present the concepts and definitions of physical activity as they apply to this body of work, outlined in Table 1.

**Table 1.** Concepts and definitions of physical activity and sedentary behaviour

<b>Physical activity</b>	
<b>Definition</b>	Physical activity is any bodily movement produced by skeletal muscles that results in energy expenditure. <sup>91</sup>
<b>Behaviour</b>	Standing, walking, jogging, running, swimming, cycling, sport, dancing, water activities, lifting heavy things, digging, housework (including domestic, maintenance, yard work, and childcare), fidgeting, posture maintenance, and lifestyle-embedded movement
<b>Modality</b>	Mode of physical activity may include leisure or non-leisure physical activity.
Leisure	Physical activity undertaken during leisure time, such as exercise (planned and structured physical activity undertaken to improve or maintain physical fitness components <sup>91</sup> ), sport, and recreational physical activities.
Non-leisure	Physical activity undertaken during non-leisure time, such as occupational, transport, household (including domestic, maintenance, yard work, and childcare), and lifestyle-embedded movement.
<b>Dimensions</b>	
Frequency	The number of times a dimension of physical is performed during a specific time period.
Intensity	The level of intensity of physical activity is most commonly defined by METs. MET units express the energy cost of a movement as a multiple of resting metabolic rate and is typically categorised into four levels: sedentary* (< 1.5 METs), light intensity (1.5–2.9 METs), moderate intensity (3.0–5.9 METs), and vigorous intensity (≥ 6.0 METs).
Duration	The duration of single bouts of physical activity, or the sum of time across a specific time period (i.e., day, week)
<b>Classifications</b>	
Physically active	Meeting established guidelines for physical activity; usually reflected as achieving a threshold number of minutes of MVPA per day. <sup>92</sup>
Insufficient physical activity	Not meeting established guidelines for physical activity.

<b>Sedentary behaviour</b>	
<b>Definition</b>	Sedentary behaviour is any waking behaviour characterized by an energy expenditure $\leq 1.5$ METs while in a sitting or reclining posture. <sup>93</sup>
Sedentary time	Sedentary time refers to an estimation of sedentary behaviour from accelerometers which is determined by epochs with very low, or no activity counts ( $< 100$ counts per minute; cpm).
<b>Behaviour</b>	Sitting, reclining posture, lying down
<b>Modality</b>	Mode of sedentary behaviour may include leisure or non-leisure behaviours.
Leisure	Sedentary behaviours during leisure time, such as television viewing, or playing games on computer or console.
Non-leisure	Sedentary behaviours during non-leisure time, such as sitting at work or while travelling.
<b>Dimensions</b>	
Frequency	The number of bouts of a certain duration. <sup>92</sup>
Interruptions	The number of breaks in sedentary behaviour or sedentary time. <sup>92</sup>
Duration	The duration of sedentary behaviour or sedentary time. <sup>92</sup>
<b>Classifications</b>	
Sedentariness	Extended engagement in behaviours characterised by minimal movement, low energy expenditure, and rest. <sup>92</sup>

\*Sedentary intensity is regarded as  $< 1.5$  METs, however not all behaviours below this threshold are genuine sedentary behaviours.

## Summary

Physical activity is a positive lifestyle behaviour that is essential for the maintenance of optimal health and prevention of non-communicable diseases. Traditionally, MVPA was thought to be the minimum level of activity required to achieve health benefit, hence public health guidelines which recommend adults perform at least 150 min of moderate-intensity physical activity per week.<sup>42</sup> These recommendations have remained largely unchanged in 18 years<sup>51</sup> even with substantial growth in knowledge. Of critical importance is that despite significant public health efforts over the last two decades, the prevalence of insufficient physical activity remains high. What is more, societal levels of daily-living physical activity have declined over-time and sedentariness has become widespread; some predict that society has not yet reached the pinnacle of sedentariness.<sup>71,74</sup> With chronic non-communicable disease the leading cause of death worldwide,<sup>41</sup> increasing physical activity continues to be a major public health priority.

There is an emerging perspective in physical activity epidemiology that moves beyond MVPA to a broader whole-of-physical activity approach, where physical activity in all areas of life and at all intensities is important for health. A key driver of this perspective is developments in measurement technology which have enabled a broader assessment of physical activity across the spectrum of intensity. This has led to new evidence that sedentary behaviour presents an adverse risk to health and that physical activity at light-intensity plays a crucial role in reducing levels of sedentary behaviour. Although emergent, such evidence is convincing and new areas of research are appearing. One of these areas is the utility of accelerometers to provide insights into the patterns of physical activity accumulation and complete profiles of physical activity and sedentary behaviours. Research in this area will develop understanding of the optimal patterns of physical activity for health, such as the duration of bouts, accumulated vs. episodic physical activity, and the balance of sedentary, light, moderate, and vigorous intensity physical activity.

Social demography may explain some of the variances in patterns of physical activity. It is known that adults with young children have different patterns of time use than adults without children,<sup>94,95</sup> as such differences in patterns of physical activity are probable. These general population sub-groups offer an ideal case to apply a whole-of-physical activity perspective to examine variances in patterns and profiles of physical activity.

## **The context of early parenthood**

*“To be a mother is to take on one of the most emotionally and intellectually demanding, exasperating, strenuous, anxiety-arousing and deeply satisfying tasks that any human being can undertake.” (Kitzinger, 1992, p.viii)<sup>11</sup>*

Having a child is a normal life event experienced by a majority of the adult population. Becoming a parent for the first time is a significant life change event that requires an adjustment in an adults' pattern of living.<sup>96</sup> New parents assume complete responsibility for the care and wellbeing of their child and face a new pattern of life, a new role, and a new identity. Although parents' investment in their child's life continues until adulthood, and even beyond, the preschool years involve the greatest level of daily care and responsibility.<sup>94,97</sup> These early years and are also thought to exert the greatest influence over opportunities for parents' participation in physical activity.<sup>35,98,99</sup>

Time use studies provide valuable information on differences in the way adults with and without children spend their time. Data from the 2009/10 New Zealand Time Use study show that New Zealand adults with children (aged less than 15 years) had lower participation rates and spent less time in sports and hobbies and free time, and had higher participation rates and spent more time in childcare than adults with no children (Table 2). Furthermore, women with children spent less time in labour-force activity, whereas men with children spent more time in labour-force activity than those without children. These data indicate that time for childcare largely replaces time for personal care and leisure time activities; however these estimates are for adults of all ages and children are those aged < 15 years. Data on time spent in childcare for partnered adults with a child aged < 5 years provide greater insights into care of young children.<sup>100</sup>

Highlights from these data show that:

- **Mothers spend more time caring for young children in the same household than do fathers.** Excluding time spent sleeping, mothers spend, on average, 12 hr and 20 min in childcare, compared to 6 hr and 34 min for fathers. When sleep is included, mothers spend,

**Table 2.** Daily participation and average daily time spent in primary activities, New Zealand adults 2009/10

	Men			Women		
	Couple with child	Solo with child	Couple no child	Couple with child	Solo with child	Couple no child
Daily participation rate, primary activities (%) <sup>101</sup>						
Personal care	100	100	100	100	100	100
Labour Force activity	70	58	50	37	28	41
Household work	77	92	86	97	96	96
Childcare	63	56	4	83	76	9
Sports and hobbies	27	37	36	27	25	37
Mass media and free time	89	87	95	92	95	95
Average daily time spent, primary activities (hr:min) <sup>102</sup>						
Personal care	10:14	10:01	10:55	10:38	11:08	11:04
Labour Force activity	6:10	4:57	4:02	2:17	1:49	2:56
<i>of those who participated</i>	<i>8:46</i>	<i>8:29</i>	<i>8:01</i>	<i>6:08</i>	<i>6:37</i>	<i>7:06</i>
Household work	1:25	2:10	2:01	2:58	2:41	2:56
Childcare	0:59	1:20	0:04	2:20	1:55	0:11
Sports and hobbies	0:34	0:41	0:44	0:22	0:28	0:33
Mass media and free time	2:21	2:36	3:39	2:12	2:43	3:13

Couple: two people who usually reside together and are legally married or in a civil union, or two people who are in a consensual union; Solo: the parent in a one-parent family; Child: aged under 15 years. Source: Statistics New Zealand Time Use 2009/10.<sup>101, 102</sup>

on average, 19 hr and 55 min per day caring for a child; this includes active childcare as a primary and secondary activity, passive childcare (not actively caring for child, but under the respondents' care), and time spent sleeping.

- **Mothers and fathers spend their childcare time in different types of care.** Fathers spent a greater proportion of their active childcare time on recreational care than did mothers (41% vs. 23%, respectively), and mothers spent a greater proportion of their active childcare time on physical care than did fathers (59% vs. 40%, respectively).
- **On weekends mothers and fathers provide more joint care than on weekdays.** Mothers provided the greatest proportion of childcare on weekdays (59%), followed by joint care (34%) and fathers only (6%). On weekends, however, childcare was mostly through joint care (59%), followed by mothers only (33%), and fathers only (8%).
- **Differences in childcare time are evident across dual-income and single-income families.** In families with the father working full time, mothers who are also working full-time spend less time per day in childcare (5 hr 32 min\*) than do mothers who are not working (9 hr and 13 min\*). Fathers spend more time per day in childcare when both parents are working full-time (1 hr and 40 min\*) than do fathers when the mother is not employed (15 min\*). \*These data relate to the period of time from 6 am to 9 pm (15 hr).

New Zealand families are similar to other developed countries, with trends towards having children later and smaller families.<sup>103</sup> Couples with children are the most common household type, of which 72% are two-parent families and 28% are one-parent families.<sup>103</sup> While trends indicate that more women are remaining childless,<sup>104</sup> those aged between 30 and 34 years have the highest fertility rate (125 births per 1,000 women), followed by those aged between 25 and 29 years.<sup>105</sup> Parental leave from employment is widespread in New Zealand with statutory paid parental leave provisions for mothers and partners (14 weeks paid leave and up to 52 weeks in total). By 6 months after commencing parental leave, 40% of women had returned to work, in some capacity, and 68% by 18 months.<sup>106</sup> Participation in early childhood education is subsidised by government for children aged 3–5 years; 14% of children < 1 year of age, 58% of 2-year-old children, and 94% of 3-year-old children are enrolled in early childhood education services.<sup>107</sup>

## **Parenthood and physical activity**

Epidemiological studies first identified motherhood as an influential factor in women's physical activity participation in the early 1990s, most notably in the Canadian Women's Health Study (N = 5,939).<sup>108</sup> This study found that women who had children aged less than 17 years were significantly less likely to participate in regular strenuous exercise, and participated in significantly less exercise than women without children. Since this research epidemiological studies have continued to document associations between parenthood and comparatively low levels of physical activity. The following section contains a broad review of the current state of knowledge of physical activity behaviour in women and men with young children.

### **Physical activity and parent status**

A number of cross-sectional and prospective studies have documented a negative association between parenthood and various dimensions of physical activity (Table 3). The majority of these studies were conducted with women, however seven of these studies included samples of men, and one study was conducted solely in a sample of men (N = 783).<sup>109</sup> Although the overwhelming majority of studies have shown that women with children have lower levels of physical activity than those without children, a few studies have shown no association in women<sup>15,36,110-114</sup> and men.<sup>15,115,116</sup> Moreover, a few studies have reported a positive association between parenthood and household or caregiving physical activity, with parents reporting more physical activity than non-parents.<sup>14,15,111</sup>

Of the studies reporting no association with parenthood, two studies<sup>110,111</sup> were of adults with children aged < 18 years, which may lack sensitivity for the effect of young children on activity levels. Another study<sup>112</sup> compared a maternity group ((n = 42 women who were pregnant at recruitment) and a control group (n = 201 women not pregnant at recruitment), however the control group were older, had lower average income, and 74% were mothers; which is likely to contribute to the lack of an observed association. Two studies observed no association between having a young child (aged 0–5 years)<sup>15</sup> or being a married mother<sup>36</sup> and accelerometer-derived MVPA. However another study<sup>35</sup> (N = 2,315) observed differences in accelerometer-derived MVPA that was accumulated in bouts of at least 10 min, between adults with and without young children.

**Table 3.** Studies examining the association between parent status and physical activity

Study	Objective	Sample	Physical activity outcome variable	Physical activity and parent status	Assoc.
<b>Women</b>					
Verhoef et. al., <sup>108</sup> 1992  Cross-sectional Canada Women's Health Study	Determine the relative importance of social roles and their characteristics with women's exercise participation.	5,939 Women  Child age: < 17 y	Self-report: Participation Y/N Hr/week  Exercise	Mothers were less likely to exercise ( $p < .001$ ) and exercised less ( $p < .001$ ) than non-mothers.	–
Verhoef and Love <sup>117</sup> 1992  Cross-sectional Canada	Determine the relevance of social roles compared with non-role-related determinants of women's exercise participation.	1,113 Women  Child age: < 17 y	Self-report: Exercising Y/N Moderately active Very active  Exercise	Mothers were less likely to exercise (OR 1.66, $p < .001$ ), and of those who exercised they were less likely to be very active (OR 1.88, 95% CI 1.17-3.2, $p < .05$ ).	–
Verhoef and Love <sup>98</sup> 1994  Cross-sectional Canada	Investigate differences in exercise participation, barriers, and benefits, between mothers and non-mothers	1,113 Women  Child age: < 17 y	Self-report: Min/week  Exercise	Mothers participated in less strenuous and moderate exercise ( $p < .01$ ) than non-mothers. There was no difference in mild exercise.	– 0
Marcus et. al., <sup>110</sup> 1994  Cross-sectional United States	Examine utility of three theoretical models in understanding exercise behaviour among employed women	431 Women  Child age: < 18 y	Self-report: Moderate Vigorous (min/week)  Leisure	Presence of children in the home was not significantly associated with the number of minutes of vigorous or moderate activity during the previous seven days. Fewer women in the Action and Maintenance stages of physical activity behaviour change had children ( $\chi^2 = 6.25$ , $df = 2$ , $p < .05$ ).	0



Barnekow-Bergkvist et al., <sup>115</sup> 1996	Investigate gender-related differences in physical activity at ages 16 and 34 years, and determinants of physical activity in adulthood.	194 Men 179 Women *at follow-up	Self-report: Insufficiently active (PA < 1x week)	Women with children were more likely to be insufficiently active (AOR 12.1, 95% CI 2.1-69.1) than women without children.	–
Prospective Sweden		Child age: n.r.	Leisure		
Sternfeld et.al., <sup>14</sup> 1999	Assess the level of physical activity in various domains in a large sample of women, and compare domain-specific correlates of activity.	2,636 Women	Self-report: Scale 1-5 per domain	Having young children was associated with lower odds of high Sport and Exercise (AOR 0.60, 95% CI 0.42-0.87) and higher odds of high household/caregiving activity (AOR 4.4, 95% CI 3.24-5.98).	– +
Cross-sectional United States		Child age: ≤5 y	Occupational Sports and exercise Other LTPA Household/caregiving		
Scharff et. al., <sup>111</sup> 1999	Investigate characteristics associated with physical activity across different stages in women's lives.	653 Women	Self-report: PA daily living (7x30 min/week) LTPA (3x30 min/week)	Having children at home increased odds of performing adequate physical activities of daily living among women aged 18-29 years (OR 3.1, 95% CI 1.7-5.7, $p < .001$ ) and 30-39 years (OR 6.5, 95% CI 1.9-21.0, $p < .01$ ), but not leisure-time activities.	+ 0
Cross-sectional United States		Child age: < 18 y			
Brown et. al., <sup>118</sup> 2000	Explore associations between leisure-time physical activity and health and wellbeing among women.	14,502 Women (young cohort)	Self-report: PA Score 0-80	Women living with children had lower mean physical activity scores than women not living with children ( $16.4 \pm 14.4$ vs. $19.1 \pm 14.1$ , $p < .05$ ).	–
Cross-sectional Australia ALSWH: 1996		Child age: n.r.	Exercise		
Burton and Turrell <sup>119</sup> 2000	Examine relationship between occupations, hours of employment and participation in leisure-time physical activity.	13,425 Men 11,029 Women	Self-report: Insufficiently active (< 1600 MET min/fortnight)	Women with children more likely to be insufficiently active than those living alone (OR 2.28, 95% CI 1.9-2.7).	–
Cross-sectional Australia Australian National Health Survey: 1995		Child age: < 18 y	Exercise		

Brown et. al., <sup>120</sup> 2003	Compare the time spent in different sitting activities among a sample of mothers and a sample of workers.	529 Mothers 185 Workers	Self-report: Sitting time Hr/day	Mothers spent almost 6 hr less per day sitting than workers ( $t(722) = 30.79, p < .001$ ).	+
Cross-sectional Australia		Child age: < 5 y	Sitting		
			Self-report: Sufficient LTPA ( $\geq 150$ min/week)	Mothers were less likely to achieve sufficient levels of LTPA than workers ( $p < .05$ ).	-
			Leisure		
Brown and Trost <sup>121</sup> 2003	Determine whether key life events experienced by young women in their early twenties are associated with increasing levels of inactivity.	7281 Women (young cohort)	Self-report: Inactive (< 600 MET min per week)	Young women having their first baby had higher odds of being inactive at follow-up than those who did not have first baby (OR 1.78, 95% CI 1.53-2.08, $p < .0001$ ).	-
Prospective Australia ALSWH; 2000		Child age: n.r.	Leisure		
Burke et. al., <sup>116</sup> 2004	Examine associations between changes in social circumstances and changes in risk factors and health-related behaviours at age 25 years.	194 Men 211 Women *both surveys	Self-report: PA min/week	More women with children achieved less than 90 min of physical activity per week than women without children ( $p = .02$ ).	-
Prospective Australia		Child age: n.r.	Leisure		
			Fitness: Sub-maximal cycle test	Fitness decreased among women who had children, compared to an increase among women with no children ( $p = .001$ ).	-
Nomaguchi and Bianchi <sup>99</sup> 2004	Examine the relationship between major work and family roles and time spent on exercising.	5,984 Men 7,512 Women	Self-report: Time previous 2 weeks.	Women with children < 5 years spent less time exercising than women no children < 5 years ( $p < .01$ ). There were no differences in time spent exercising among women with and without children < 18y.	- 0
Cross-sectional United States National Health Interview Survey, 1995		Child age: < 5 y < 18 y	Exercise		

Bell and Lee <sup>122</sup> 2005  Prospective Australia ALSWH: 1996, 2000	Explore whether women's transitions in life domains during emerging adulthood are related to physical activity.	8,545 Women  Child age: n.r.	Self-report: Inactive (< 600 MET min per week)  Leisure	At survey 1 (1996) mothers were more likely to be inactive than non-mothers (OR 1.8, 95% CI 1.4-2.2, $p < .0001$ ). At survey 2 (2000) mothers were more likely to be inactive than non-mothers (OR 2.2, 95% CI 1.9-2.5, $p < .0001$ ). Women who became mothers between survey 1 and 2 were more likely to decrease physical activity (OR 1.6, 95% CI 1.3-2.0, $p < .001$ ), or remain inactive (OR 1.7, 95% CI 1.4-2.0, $p < .0001$ ), and less likely to remain active (OR 0.5, 95% CI 0.4-0.6, $p < .001$ ) or increase physical activity (OR 0.7, 95% CI 0.6-1.0, $p < .01$ ).	–
Grace et. al., <sup>112</sup> 2006  Prospective	Investigate women's health-promoting behaviours across transitions from pregnancy to maternity leave and return to work, and compare behaviours in maternity and non-maternity samples.	243 Women  Child age: n.r.	Self-report: Scale 1-4  Physical activities	There was no difference in physical activity between the maternity group and comparison group, after the maternity group had returned to work.	0
Choi et. al., <sup>123</sup> 2008  Cross-sectional United States	Describe the physical activity behaviour, and correlates of physical activity behaviour, of Korean immigrant women in the United States.	221 Women  Child age: < 5 y	Self-report: Min/week  Leisure	Korean immigrant women with young children spent less time in LTPA than women without young children (OR 0.39, 95% CI 0.22-0.70).	–
Tavares et. al., <sup>114</sup> 2009  Intervention Canada	Identify key social-cognitive theories and constructs that are most salient for explaining physical activity intention, stage of change, and behaviour among employed women with and without young children.	1,183 Women  Child age: < 13 y	Self-report: Energy Expenditure  Exercise	There was no significant difference in exercise-related energy expenditure between women with young children and women without children.	0

Brown et. al., <sup>124</sup> 2009  Prospective Australia ALSWH: 2000, 2003	Examine changes in physical activity and the relationship with life events over a 3-year period.	7,173 Women (young cohort)  Child age: n.r.	Self-report: Low active < 600 MET min/week Active ≥ 600 MET min/week  Leisure	Women who became mothers were more likely to decrease physical activity (AOR 1.45, 95% CI 1.23-1.70, $p < .001$ ) and less likely to increase physical activity (AOR 0.65, 95% CI 0.53-0.80, $p < .001$ ). Women who had a subsequent child were more likely to decrease physical activity (AOR 1.26, 95% CI 1.03-1.55, $p < .05$ ) and less likely to increase physical activity (AOR 0.78, 95% CI 0.62-0.99, $p < .05$ ).	–
Hull et. al., <sup>113</sup> 2010  Prospective United States	Explore the effects of marriage and parenthood on the physical activity levels of young adults over two years.	297 Men 349 Women  Child age: n.r.	Self-report: Hr/week  Leisure physical activities	There was no significant difference in physical activity change between women who had a first child and women who remained childless ( $p = .26$ )	0
Berge et. al., <sup>125</sup> 2011  Cross-sectional United States Project EAT: 2003/04, 2008/09	Examine whether parents of young children report different dietary intake, physical activity, and BMIs compared with young adults without children.	611 Men 769 Women  Child age: < 5 y	Self-report: Total PA MVPA (min/week)  Exercise	Women with young children reported less total exercise per week ( $p = .05$ ) and less MVPA per week ( $p = .002$ ) than women without children.	–
Adamo et al. <sup>35</sup> 2012  Cross-sectional Canada Canadian Health Measures Survey: 2007-09	Examine the influence of dependent children on parental physical activity levels measured by accelerometry.	1,078 Men 1,237 Women  Child age: < 6 y 6-11 y 12-17 y	Accelerometer: MVPA bouts ≥10 min /week	Women with children aged < 6 years accumulated fewer MVPA minutes in bouts ≥10 min than women with no dependent children ( $p < .05$ ).	–

Candelaria et. al., <sup>15</sup> 2012	Compare differences in physical activity between adults with and without children living in the household.	965 Men 909 Women	Self-report: Min/week	Women with young children (0-5y) reported significantly more time in household physical activity than women with no children ( $p < .05$ ). No other physical activity differences were observed. Women with young children reported significantly less time sitting than women with no children and women with older children ( $p < .05$ ).	+ 0 –
Cross-sectional United States Neighborhood Quality of Life Study		Child age: 0-5 y 6-12 y 13-17 y	Leisure Occupation Transport Household Sitting		
			Accelerometer: MVPA min/week	No significant differences in accelerometer-derived MVPA min were observed between women with young children (0-5y) and women without young children.	0
Dlugonski and Motl <sup>36</sup> 2013	Pilot study to compare the magnitude of differences in physical activity among unmarried mothers, married mothers, and non-mothers using objective and self-reported measures.	66 Women	Self-report: MET min/week	Unmarried mothers reported significantly less exercise than non-mothers ( $p < .05$ , $d = 1.02$ ). No significant differences were observed between mother and non-mother groups for total MET min per week of LTPA. No significant differences were observed between married mothers and non-mothers ( $p < .05$ ).	– 0
Cross-sectional United States		Child age: < 5 y < 18 y	Exercise LTPA		
			Accelerometer: MVPA min/week	Unmarried mothers recorded significantly fewer minutes of MVPA than non-mothers ( $p < .05$ , $d = 0.93$ ). No significant differences were observed between married mothers and non-mothers ( $p < .05$ ).	– 0
<b>Men</b>					
Barnekow-Bergkvist et. al., <sup>115</sup> 1996	Investigate gender-related differences in physical activity at ages 16 and 34 years, and determinants of physical activity in adulthood.	194 Men 179 Women *at follow-up	Self-report: Insufficiently active (PA < 1x week)	Having children was not associated with insufficient LTPA among men.	0
Prospective Sweden		Child age: n.r.	Leisure		

Burton and Turrell <sup>119</sup> 2000	Examine relationship between occupations, hours of employment, and participation in leisure-time physical activity.	13,425 Men 11,029 Women  Child age: < 18 y	Self-report: Insufficiently active (< 1600 MET min/fortnight)  Exercise	Men with children more likely to be insufficiently active than those living alone (OR 1.69, 95% CI 1.5-1.9).	–
Cross-sectional Australia Australian National Health Survey: 1995					
Burke et. al., <sup>116</sup> 2004	Examine associations between changes in social circumstances and changes in risk factors and health-related behaviours at age 25 years.	194 Men 211 Women *both surveys  Child age: n.r.	Self-report: PA min/week  Leisure  Fitness: Sub-maximal cycle test	There was no significant difference in the number of men achieving less than 90 min of physical activity per week between men with and without children ( $p = .22$ )  There was no significant difference in fitness change between men with and without children ( $p = .12$ ).	0  0
Prospective Australia (2004). 2004  Prospective Australia					
Nomaguchi and Bianchi <sup>99</sup> 2004	Examine the relationship between major work and family roles and time spent on exercising.	5,984 Men 7,512 Women  Child age: < 5y < 18y	Self-report: Time previous 2 weeks.  Exercise	Men with children < 5 years spent less time exercising than men with no children < 5 years ( $p < .001$ ). Men with children < 18 years spent less time exercising than men with no children < 18 years ( $p < .001$ ).	–
Cross-sectional United States National Health Interview Survey, 1995					
Nielsen et. al., <sup>109</sup> 2006	Identify correlates of obesity and inactivity in a population-based cohort of Danish men, aged 20-29 years.	783 men  Child age: n.r.	Self-report: Participation Y/N  Types of physical activities	Men with one or more children were more likely to not participate in physical activity than men with no children (OR 2.3, 95% CI 2.0-4.3, $p < .00005$ ).	–
Cross-sectional Denmark					

Hull et. al., <sup>113</sup> 2010	Explore the effects of marriage and parenthood on the physical activity levels of young adults over two years.	297 Men 349 Women	Self-report: Hr/week	Men who had a first child decreased their physical activity significantly more than men who remained childless ( $p = .05$ )	–
Prospective United States		Child age: n.r.	Leisure physical activities		
Berge et. al., <sup>125</sup> 2011	Examine whether parents of young children report different dietary intake, physical activity, and BMIs compared with young adults without children.	611 Men 769 Women	Self-report: Total PA MVPA (min/week)	Men with young children reported less MVPA per week ( $p = .01$ ) than men without children, but there were no significant differences in total physical activity per week ( $p = .10$ ).	– 0
Cross-sectional United States Project EAT: 2003/04, 2008/09		Child age: < 5 y	Exercise		
Adamo et al. <sup>35</sup> 2012	Examine the influence of dependent children on parental physical activity levels measured by accelerometry.	1,078 Men 1,237 Women	Accelerometer: MVPA bouts $\geq 10$ min /week	Men with children aged 6–11 years accumulated fewer MVPA minutes in bouts $\geq 10$ min than men with no dependent children ( $p < .05$ ).	–
Cross-sectional Canada Canadian Health Measures Survey: 2007-09		Child age: < 6 y 6-11 y 12-17 y			

Candelaria et. al., <sup>15</sup> 2012	Compare differences in physical activity between adults with and without children living in the household.	965 Men 909 Women	Self-report: Min/week	Men with young children (0–5y) reported significantly more time in household physical activity than men with no children ( $p < .05$ ). No other physical activity differences were observed. Men with young children reported significantly less time sitting than men with no children ( $p < .05$ ).	+ 0
Cross-sectional United States Neighborhood Quality of Life Study		Child age: 0-5 y 6-12 y 13-17 y	Leisure Occupation Transport Household Sitting		
			Accelerometer: MVPA min/week	No significant differences in accelerometer-derived MVPA min were observed between men with young children (0–5y) and men without young children.	0

Assoc. = Association; AOR = adjusted odds ratio; LTPA = leisure-time physical activity; MVPA = moderate-to-vigorous physical activity; n.r. = not reported; y = years.



These findings from accelerometer studies suggest that overall amounts of objectively-measured physical activity may not differ substantially between parents and non-parents, however there may be differences in the way in which it is accumulated. In studies of adults with young children, men with young children were more likely to be insufficiently active,<sup>119</sup> not participate in physical activity,<sup>109</sup> spend less time exercising,<sup>99,113,125</sup> and recorded fewer accelerometer-derived MVPA minutes in bouts of  $\geq 10$  min<sup>35</sup> than men without children. No association was found for parenthood with total accelerometer-derived MVPA,<sup>15</sup> and men with children reported more household-related physical activity than men without children.<sup>15</sup> Specifically in studies examining the effects of having a young child on women's physical activity, mothers participated in less sport and exercise physical activity,<sup>14,99,125</sup> and leisure-time physical activity,<sup>120,123</sup> recorded fewer accelerometer-derived minutes of MVPA (bouts  $\geq 10$  min),<sup>35</sup> and reported more household-related physical activity<sup>15</sup> than non-mothers.

### ***Tracking of physical activity***

Although it is posited that the transition to parenthood changes physical activity behaviour, only a few studies have reported effects of becoming a parent on physical activity levels in longitudinal studies (Table 3).<sup>113,116,122,124</sup> These studies monitored physical activity in cohorts of women and men over periods ranging from two to seven years; at follow-up, amongst other items participants (mean age range 25–28 years) reported whether or not they had had a child during the study period. All but one<sup>113</sup> of these studies found that self-reported physical activity decreased among those who had become mothers, although results were equivocal among men.<sup>113,116</sup> The age of participants at follow-up in two of these studies (22–27 years;<sup>122</sup> 25 years<sup>116</sup>) are lower than the median age for first-time mothers in New Zealand (28 years<sup>126</sup>) and it has been suggested that early parenthood (i.e., earlier than the average<sup>127</sup>) is associated with additional lifestyle and social factors, such as socio-economic disadvantage, lower levels of education, and unhealthy lifestyle behaviours.<sup>127</sup> As such, caution is warranted in interpreting findings from these studies.

The strongest evidence for the effects of becoming a mother on women's physical activity can be drawn from published results of the Australian Longitudinal Study of Women's Health (ALSWH);<sup>124</sup> this large representative study followed three cohorts of women ('young' cohort aged 18–23 years) in Australia across three time points from 1996 to 2003. Although findings

from the first-to-second time points showed that women who became mothers were more likely to decrease their self-reported physical activity, or remain inactive, than those who remained childless.<sup>122</sup> Different self-report tools were used between time-points; however, similar results were found between the second and third time points of the ALSWH at which identical self-report tools were employed. After adjustment for potential confounders, women in the younger cohort ( $n = 7,173$ , aged 25–30 years at follow-up) who became mothers (16%) were significantly more likely to decrease weekly MVPA (OR = 1.5, 95% CI 1.2–1.7) than those who remained childless.<sup>124</sup>

Other studies in mothers have used retrospective recall of pre-pregnancy physical activity levels to investigate changes in behaviour. Three studies reported that physical activity declined from pre-pregnancy to motherhood,<sup>12,128,129</sup> however one study reported no change in physical activity.<sup>130</sup> In a study of 2,128 women recruited within 22 weeks gestation, participants reported their physical activity from 12 months pre-pregnancy (retrospective recall), during pregnancy (7 day recall), and 6-months post-partum (7 day recall).<sup>12</sup> Findings from this study showed that levels of walking and leisure-time physical activity decreased from pre-pregnancy to pregnancy. While walking returned to pre-pregnancy levels by 6-months postpartum only some of the decline in leisure-time physical activity during pregnancy was regained post-partum, and levels remained lower than pre-pregnancy.

Few other studies have tracked physical activity levels post-motherhood; two studies monitored behaviour during the immediate post-partum period (< 12 months) and found no changes in physical activity behaviour.<sup>131,132</sup> Another study tracked physical activity at four time-points across seven years in an ethnically-diverse sample of 129 mothers using the 7 day Physical Activity Recall instrument (PAR). Findings showed that during this period European-American women significantly increased vigorous leisure, moderate leisure, vigorous work and moderate work physical activity, and Mexican-American women increased vigorous leisure, moderate leisure, and moderate work physical activity; there were no significant ethnic variations in change.<sup>133</sup> Although it was posited that this increase in physical activity may relate to the increasing age of their child, further analyses did not confirm this hypothesis.

### ***Amounts of physical activity***

A common prevalence indicator from self-reported physical activity is based on the proportion of a study sample that meets recommended physical activity guidelines for health. However, many studies of parental physical activity have not reported this information and between-studies comparisons of physical activity levels are problematic due to the wide variety of instruments employed, constructs measured, guidelines and scoring protocols, and demographically different samples.<sup>134</sup> Four studies have reported comparable prevalence rates of mothers attaining  $\geq 150$  min MVPA per week in samples of women<sup>122</sup> and mothers.<sup>19,120,135</sup> Collectively, these studies estimate more than half of mothers (51–66%) are insufficiently active, compared to approximately 42% of non-mothers.<sup>120,122</sup> Globally, 31% of adults are considered insufficiently active, and this rate is higher among women (34%).<sup>10</sup>

Objectively-monitored physical activity has become commonplace in physical activity epidemiology, however only in the last two years have published studies reported accelerometer-derived physical activity in adults with young children. Two large cross-sectional studies compared accelerometer-assessed physical activity of adults with and without young children. Data from the Canadian Health Measures Survey ( $n = 2,315$ , 19% with child aged  $< 6$  years) showed that women and men with young children recorded on average 18 min (95% CI 14–22) and 26 min (95% CI 24–27), respectively, of MVPA per day (recorded in physical activity bouts of at least 10 min).<sup>35</sup> Estimates were slightly higher in the U.S. Neighborhood Quality of Life Study of 1,874 adults (19% with child aged  $< 6$  years), with 23 min (95% CI 20–26) among women and 36 min (95% CI 32–41) among men with young children; although differences in accelerometer unit and data treatment existed between the studies. Specifically, a minimum bout criterion was not applied to accelerometer-determined MVPA in the latter study and all minutes of MVPA were included in analyses.<sup>15</sup> A smaller study ( $n = 66$ ) showed that unmarried mothers recorded on average 22 min ( $SD$  20 min) and married mothers 33 min ( $SD$  20 min), and another small study ( $n = 104$ ) investigating the relationship between parent and child physical activity estimated that mothers spent 4.7%, and fathers spent 5.6%, of accelerometer wear-time in MVPA on weekdays.<sup>136</sup>

Comparable general population data from the Canadian Health Measure's Survey<sup>137</sup> (Actual accelerometers) show that women recorded on average 21 min of MVPA per day and 27 min

per day for men, only marginally different from than those reported for the parent sample above.<sup>35</sup> However direct comparison of the parent and non-parent sample do show significant differences for women with and without children aged 0–5 years (Table 3).<sup>35</sup> Estimates from the 2003-04 National Health and Nutrition Examination Survey (NHANES) obtained from Actigraph accelerometers for adults aged 30–39 years are higher among men (43 min of MVPA per day), although similar among women (21 min of MVPA per day).<sup>138</sup> Cross-study comparisons of different monitors, with varying data treatment procedures can be difficult.<sup>83,84</sup>

While accelerometer-derived estimates of parents' physical activity is fairly recent, previously pedometers have been employed in a few small-scale studies among women<sup>139-142</sup> and men.<sup>141</sup> Two of these studies reported low step counts (5,700–5,800 steps per day) in samples of sedentary and overweight low-income mothers with young children.<sup>140,142</sup> However, higher estimates have been reported in a sample of women at 3-months postpartum ( $6,300 \pm 2,700$  steps per day),<sup>139</sup> and in a sample of healthy mothers and fathers ( $6,800 \pm 2,700$  and  $6,400 \pm 2,700$  steps per day, respectively).<sup>141</sup> These daily step counts are significantly below the recommended level of 10,000 steps per day, however they are comparable with other prevalence estimates of pedometer steps among women, irrespective of their parenthood status ( $5,210 \pm 3,518$  steps per day).<sup>143</sup>

### ***Sedentary behaviour***

Sedentary behaviour has been a neglected dimension of research on parental physical activity behaviours and is currently limited to self-report estimates of sitting time. A number of studies published recently incorporated accelerometer technology however none of these studies reported accelerometer-derived estimates of sedentary time from accelerometer outputs.<sup>15,35,36,136</sup> Wide variations in self-reported estimates of sitting time have been reported in four cross-sectional studies using the International Physical Activity Questionnaire (IPAQ),<sup>15,120</sup> Active Australia survey<sup>144</sup> and modified 7 day PAR.<sup>139</sup> Average sitting time was 3.5 hr per day in a sample of women with children aged < 5 years.<sup>120</sup> Comparably, a sample of men and women reported sitting time estimates of 4.8 hr per day in women with young children and 5.4 hr per day in men with young children.<sup>15</sup> However, in a sample of low-income mothers with a 3-month old infant estimates were higher, with an average of 9.0 hr per day spent sitting.<sup>139</sup> This higher estimate may reflect a significant period of the day spent feeding a new born baby.

Compared with non-parents, average sitting time was lower for mothers than non-mothers (4.8 vs. 6.5 hr per day,  $p < .05$ ) and for fathers compared with non-fathers (5.4 vs. 6.4 hr per day,  $p < .05$ ) in a random sample of adults from stratified neighbourhoods in the United States.<sup>15</sup> Similarly, results from the third wave of the ALSWH showed women (aged 25 to 30 years) with children reported less sitting time than those with no children (5.8 vs. 6.6 hr per day,  $p < .001$ ).<sup>145</sup> This study also showed that women with caring duties (care for adults or children) had lower levels of sitting than women without these duties. Furthermore, an inverse relationship between level of participation in home duties and reported sitting time was shown, and this relationship was less consistent for active leisure participation.<sup>145</sup>

### **Summary**

Overall, most studies show that women and men with children are less active than adults without children. Indeed, a greater proportion of mothers have been shown to be insufficiently active ( $< 150$  min MVPA per week) than estimates for women in the general population. Furthermore, limited tracking data suggests that physical activity decreases from pre-parenthood to post-parenthood, particularly among women. On the other hand, a few studies indicate that parents spend less time sitting per day than non-parents. Current knowledge is presently limited by a paucity of studies in men with young children, short-term tracking of physical activity on the transition to parenthood and post-parenthood, and an emphasis on self-reported exercise and leisure-time physical activity. It is possible that parents may accumulate physical activity via non-leisure sources.

### **Sources of parental physical activity**

Most studies in parents have explored physical activity from leisure and exercise sources and the relative contribution of physical activity from other sources has been mostly unrecognised. A key advantage of self-report assessments of physical activity is the ability to provide contextual information on types of physical activity. However, while a number of studies have assessed overall physical activity across leisure and non-leisure (household, caregiving, occupational, and transport) domains, only a few have reported non-leisure estimates of physical activity. This section reviews the available evidence for specific sources of physical activity among parents.

Sport and exercise habits have been reported in a number of studies in adults with and without children. Compared with those without children, women with children were less likely to exercise,<sup>108,117</sup> reported less exercise per week,<sup>98,99,108,118,125</sup> and were less likely to have high levels of exercise.<sup>14</sup> Among men, those with young children exercised less than those without children,<sup>99,125</sup> and were more likely to have low levels of exercise.<sup>119</sup> Furthermore, retrospective recall of exercise behaviour indicates that women exercise less during the immediate postpartum period<sup>129</sup> and during the preschool years<sup>128</sup> than they did prior to motherhood. There is consistent evidence to support the conclusion that rates of sport and exercise physical activity are low among adults with young children.

Walking is a popular physical activity for women; two studies have reported general walking behaviour in women with young children. In their study of physical activity during the transitions from pre-pregnancy (retrospective recall) to 6-months postpartum, Pereira et al.<sup>12</sup> found that hours of walking per week declined during pregnancy, however levels of walking at 6-months postpartum were similar to pre-pregnancy levels. Another study reporting the measurement properties of a women's self-report physical activity tool, showed that the median level of brisk walking of 40 women with young children was 60 min per week.<sup>146</sup> By extension, pram walking has been identified as a popular activity among mothers. In their exploratory study of the feasibility of a community-based pram walking programme, Currie and Develin<sup>147</sup> found that 87% of respondents with a child aged < 5 years walked with a pram between two and seven times per week for incidental purposes. This included walking to the shops, to visit friends, and to calm children. Many women did not perceive this incidental use of pram walking as exercise, although around half of women did use the pram for exercise purposes. Although pram walking is a prevalent activity, it may only occur for a relatively small period during the preschool years as some women reported that children could be difficult in the pram and that they discontinued pram walking once their child got older.<sup>147,148</sup>

While occupational and transportation physical activity are also sources of physical activity for adults, few studies have investigated these behaviours in those with children. These studies found no associations between having young children and occupational physical activity<sup>14,15</sup> or transport-related physical activity,<sup>15</sup> in women or men.

A number of researchers have argued that household-related physical activity may contribute significantly to total physical activity in some populations.<sup>149-151</sup> However, only three studies have reported household-related physical activity among adults with and without young children. In a study of 653 women, having children at home was associated with increased odds (OR 3.1, 95% CI 1.7–5.7,  $p < .001$ ) of meeting physical activity guidelines through activities of daily living (including house work, home repairs, yard work, and childcare).<sup>111</sup> Similarly, Sternfeld and colleagues<sup>14</sup> found that women with young children had higher odds of high levels of household and caring physical activity (OR 4.4, 95% CI 3.2–6.0), after adjustment for potential confounders, than women without children. Furthermore, weekly minutes of household-related MVPA was significantly higher among men and women with young children than those without children.<sup>15</sup> One additional study reported household and caregiving related physical activity before and after motherhood (retrospective recall); this study found that such activity had increased in those with infants aged  $\geq 6$  months.<sup>130</sup>

Indications from time use studies support this trend for greater participation in household and childcare related physical activity. In New Zealand, time use studies have shown that partnered women with children (aged  $< 15$  years) spend on average 2 hr and 20 min in childcare, and 2 hr and 58 min in household work as primary activities, while partnered men with children spent on average 59 min per day in primary childcare, and 1 hr and 25 min in household work.<sup>101</sup> Reports of the time costs of children of different ages show that childcare time diminishes as the age of the youngest child increases, and the greatest amount of childcare is undertaken by parents with children aged under five years.<sup>94</sup> Adults with young children aged  $< 5$  years spend the most time in childcare; mothers spend over 12 hr per day in childcare compared to over 6 hr per day for fathers, exclusive of sleeping time<sup>100</sup>. There are also sex differences in the type of childcare activities; among women approximately 59% of childcare time was in physical care and 23% in play with children, while men spent 40% of time in physical care and 41% in play with children.<sup>100</sup>

The level of work involved in household and childcare varies widely. The Compendium of Physical Activities<sup>152</sup> provides indications of the MET value of various activities, including those related to household work and childcare. Many common household activities, such as vacuuming and mopping floors, hanging washing on line, or scrubbing a bathtub, are classified

as moderate intensity ( $\geq 3.0$  METs). In general, most childcare tasks such as holding, dressing, or feeding a child require light effort (2.0–3.0 METs). Similarly, general play (while sitting or standing) is classified light-intensity, however active play, such as walking or running with children, playing tag or other games, is classified as moderate-intensity during the active periods (3.5–5.8 METs). Walking and carrying a 6.8kg (15 lb) infant, around 5-months-old, is classified as 3.0 METs; it is not uncommon for a 2-year-old toddler weighing approximately 13 kg (30 lb) to be lifted and carried multiple times a day which would likely result in even greater energy expenditure. In response to low estimates of physical activity among women with young children, Brown and colleagues<sup>153</sup> measured the energy expenditure of some typical tasks associated with motherhood by indirect calorimetry. This study found walking with and without a stroller, window washing, and vacuuming to be of moderate-intensity (3.2–4.9 METs), while grocery shopping was light intensity (2.3 METs). Collectively, these values indicate that many of the household and childcare activities are of moderate intensity, although it has been argued that these activities may not be sustained for significant periods,<sup>80</sup> and thus estimates of MVPA from household and childcare activities may contain substantial error. Despite this, it is important to consider that few household and childcare activities are classified below 2.0 METs, therefore while some activities may not be sustained above the moderate intensity threshold the majority of household and childcare time is spent in non-sedentary activity ( $\leq 1.5$  METs).

It is challenging to accurately quantify these behaviours in free-living population samples. These behaviours tend to be intermittent, co-occurring, and of brief duration, however they also occur throughout most of the day. In a qualitative exploration of measuring physical activity among women with young children, women experienced major issues with accurate estimation of the frequency and duration of their activities due to multi-tasking and intermittent behaviours.<sup>154</sup> These women also found it difficult to separate activities into discrete categories, particularly due to multi-tasking, which led to duplicate reporting. Motion sensors may be more appropriate for capturing physical activity of these intermittent and simultaneous behaviours. However, information on context would be lacking and these tools fail to measure upper body movements (such as lifting, carrying, or dressing a child), which may underestimate overall physical activity.



### ***Contexts of physical activity***

Physical activity of parents may also be described as either independent or integrated.

Independent physical activity refers to physical activity undertaken without a child present and may occur alone or with other adults. Physical activity undertaken independently is likely to require advanced planning and negotiation of childcare, either from partners, family, friends, or private providers. Parents discuss advantages of independent activity, such as the additional benefits of time out from parenting responsibilities<sup>16,20</sup> and ability to perform sustained and intense physical activity.<sup>20</sup> On the other hand, integrated physical activity may be defined as activity integrated directly with children, such as through play, or indirectly through activities of daily living whilst supervising children. The advantage of integrated physical activity is that it can be undertaken within the parameters of parenthood and negotiation of childcare is not required. However, parents have reported difficulties in performing integrated physical activity that is sustained.<sup>20</sup>

Some studies of parental physical activity that is integrated with children have been undertaken. Pram-walking programs have shown mixed efficacy,<sup>148,155,156</sup> but group exercise classes with infants present show positive results.<sup>157,158</sup> Other cross-sectional studies have examined physical activity where both parents and children are active together. In a sample of parents of children aged 2–12 years, physical activity undertaken together with their children (of at least 30 min) was more frequent than parental independent activity (2.9 days vs. 1.7 days,  $p < .01$ ).<sup>159</sup> In another study of families with children aged 4 to 6 years, parents self-reported 3 days per week, totalling of 63 min ( $SD$  38 min) per week, of physical activity with their child.<sup>160</sup> Furthermore, 37% of mothers reported participating in general physical activity with their young children at least once a day, however this was the case for only 16% of fathers.<sup>136</sup> In studies of older children, matched accelerometer and global positioning system (GPS) data for parents and their children (aged 8–14 years) show a very small proportion of MVPA was undertaken together during non-school hours (approximately 2 min on weekdays and 4 min of weekend days).<sup>161,162</sup> Further analysis revealed an additional 2 min of parental MVPA undertaken while their children were sedentary nearby ( $< 50$  m).<sup>162</sup> Joint (co-occurring between child and parent) MVPA was found to occur across residential, open space, and commercial settings, while parental MPVA and concurrent child sedentary behaviour occurred most often in residential settings.<sup>162</sup>

### ***Patterns of behaviour***

Physical activity is usually quantified as an aggregate of time spent at various intensities, such as per day or per week, however the crude patterning of physical activity and sedentary behaviour is a growing area of interest. At present few studies in adult populations have examined such patterning, and no studies have profiled patterns observed in parents with young children. Indications on what patterns may look like in parents can be gathered from qualitative studies and from other disciplines. A large amount of time spent in childcare is undertaken as a simultaneous activity.<sup>95</sup> Primeau<sup>163</sup> suggests this simultaneous activity can occur either through segregation, where child interactions are interspersed with other activities, or through inclusion, where child interactions are embedded within activities. Studies of motherhood describe this as enfolded activity, which is a central tenet of mothering occupations.<sup>97,154,164</sup> This enfolded nature of parenting can result in frequent interruptions and intermittent actions; indeed, women with children at home experience a greater degree of interruptions than those without children.<sup>165</sup> Qualitative studies on parental physical activity also describe how parents' physical activity is frequently interrupted by their children.<sup>20</sup> Taken together, these studies suggest that patterns of physical activity and sedentary behaviours are likely to be intermittent among parents; however this is yet to be confirmed by empirical research.

### ***Summary***

Parents with young children have low rates of sport and exercise physical activity; however numerous opportunities exist for physical activity to be accumulated through activities of daily living. Parents spend a significant period of the day in household and childcare activities which are of at least light-intensity and some which are of moderate-intensity. Tasks such as lifting and carrying children, preparing meals and feeding, dressing and bathing, active play, and general attendance to children's needs are performed throughout the day. However, these tasks are typically intermittent and co-occurring which provides challenges for accurately quantifying the physical activity cost of these behaviours. There is a lack of understanding of the various sources of physical activity among men with young children, with current evidence limited to sport and exercise. As men with young children have lower rates of sport and exercise than

those without children, more understanding is needed of whether they achieve physical activity through other sources.

### **Factors influencing parental physical activity**

Physical activity participation is influenced by a diverse range of factors. Socio-ecological models provide a framework for understanding interpersonal, intrapersonal, social, and environmental factors that influence behaviour.<sup>166</sup> The core concept of the Socio-ecological Model is that multiple levels of influence interact to determine behaviour. Although widely adopted in studies of physical activity in adults and children, the Socio-ecological Model has to date not been incorporated in studies of parental physical activity. Another theoretical model, the Theory of Planned Behaviour, has been adopted in a number of recent studies.<sup>114,128,129,159,167-169</sup> This model provides a theoretical basis for understanding the psychosocial factors, at interpersonal and intrapersonal levels, that underlie motivation and intention. This theory argues that intention to perform a behaviour is determined by attitude towards the behaviour, perceptions of social norms, and perceived personal control and self-efficacy of performing the behaviour.<sup>170,171</sup> Other levels of influence mediate this motivation to determine actual behaviour, such as sociodemographics and environmental constraints.<sup>172</sup> The following review combines the Socio-ecological Model and Theory of Planned Behaviour to present literature on demographic, psychosocial, and environmental factors of influence on parents' physical activity behaviour.

### ***Sociodemographic factors of influence***

#### **Sex of parent**

In general, more women are insufficiently active (34%) than are men (28%).<sup>10</sup> What is of particular interest to the current investigation, however, is whether women or men are affected differently by having children. Sex-specific outcomes were presented in three prospective<sup>113,115,116</sup> and five cross-sectional<sup>15,35,99,119,125</sup> studies of physical activity among men and women. Of these studies, having children was associated with women's physical activity but not men's in two studies,<sup>115,116</sup> and associated with men's but not women's in one study.<sup>113</sup> Interestingly, these differential outcomes were only observed in the prospective studies. In

studies reporting an effect for both women and men, the relative differences were generally similar for men and women.

### Employment

Mothers with young children spend the fewest hours per week working for pay or profit than other working age adults.<sup>95</sup> On the other hand, fathers' employment is relatively unaffected by parenthood,<sup>94</sup> and they may spend marginally more time in paid work than other men.<sup>102</sup> Most mothers return to work in some capacity during the preschool years<sup>106,173</sup> and research indicates that employed mothers of young children are the most time pressured of all demographic groups.<sup>174,175</sup> Indeed, Craig<sup>174</sup> investigated time use survey data from Australia to understand how working mothers find time for their children. Findings showed that working mothers did not reduce their childcare time in direct proportion to working hours, rather they redirected time from other areas to care for their children. In particular these women had no child-free recreation time (as opposed to 24 min per day for non-working mothers).<sup>174</sup>

These facts suggest that employment status may reduce time for physical activity among mothers, however few studies have examined this relationship. Three studies show no association between employment status and mothers' physical activity,<sup>98,108,176</sup> and one study showed that increased work hours was associated with increased physical activity across seven-years in Mexican-American mothers, but not European-American mothers.<sup>133</sup> While time constraints due to work commitments was cited as a barrier to physical activity in a sample of mothers,<sup>19</sup> Verhoef and Love<sup>117</sup> showed that the relationship between employment status and physical activity was confounded by parenthood. These findings suggest that employment status has little effect on physical activity among mothers; it is likely that parenthood moderates any effect.

### Marital status

There are equivocal associations of marital status on physical activity among parents. In a large sample of women, the negative association of marital status on women's physical activity was confounded by parenthood status.<sup>117</sup> Research that has reported the effects of marital status on mothers' physical activity is conflicting. Two studies have shown married mothers to be less

active than single mothers,<sup>117,177</sup> while one study reported that married mothers engaged in exercise more frequently than single mothers.<sup>36</sup> Other research has shown no effect of marital status on mothers' physical activity.<sup>98,176,178</sup> No studies have examined physical activity and marital status among fathers. The inconsistencies in these results preclude conclusions being drawn on the association between marital status and parental physical activity.

### Family structure

Time use studies show that the birth of a first child brings considerable change to adult time allocation, however subsequent children require only marginal adjustments; consequently age of the youngest child is a more powerful predictor of childcare time than the number of children.<sup>94</sup> In their two-year prospective study, Hull et al.<sup>113</sup> found that mothers who had a subsequent child significantly decreased their physical activity compared with mothers who maintained the same number of children ( $F(1,117) = 4.7, p = .03, d = 0.52$ ); differences were not significant for fathers. Seven descriptive studies have shown no association between number of children and physical activity among mothers<sup>14,15,98,99,108,133,176</sup> and fathers.<sup>15</sup> Other research has shown greater associations with physical activity among those with a child aged < 5 years compared with older children, for women<sup>35,98,99</sup> and men.<sup>99</sup> Although, one study found significant associations with activity among men only for those with children aged 6–11 years.<sup>35</sup> These results indicate that the age of the youngest child is an important factor in adults' physical activity, and more so than the number of children.

### Ethnicity

A few studies have been conducted in ethnic-specific groups, including Korean immigrant women in the United States,<sup>123</sup> and American-Indian mothers,<sup>179</sup> however only one study has examined ethnic differences in mother's physical activity.<sup>133</sup> In this study, European-American mothers reported more vigorous leisure ( $p < .005$ ), whereas Mexican-American mothers reported more moderate work ( $p < .02$ ); there were no significant differences between ethnic groups in moderate leisure, vigorous work activities, or total physical activity. Furthermore, there were no significant ethnic differences in the extent of physical activity change across seven-years of tracking.<sup>133</sup> A review of physical activity correlates in women of different ethnicities

found that having children was negatively associated with physical activity in multiple ethnic groups, though the type of physical activity may have some ethnic-variation.<sup>180</sup>

### Socioeconomic status

Socioeconomic status has been positively associated with physical activity in the general adult population.<sup>181</sup> A few studies have been conducted in samples of low-income mothers,<sup>139,140,142,179,182</sup> including three interventions.<sup>140,142,183</sup> Two interventions showed some efficacy in increasing physical activity and improvements in behaviour change constructs,<sup>140,183</sup> and a pedometer-based intervention increased physical activity levels in low-income mothers.<sup>142</sup> Investigation of physical activity barriers among high and low socioeconomic groups indicate that mothers with a higher socioeconomic status may experience greater partner support<sup>17,19</sup> and fewer financial constraints for physical activity participation,<sup>17,19</sup> however lack of time due to family responsibilities were common in mothers irrespective of socio-economic status.<sup>17,19</sup> Indeed, a non-significant relationship between socioeconomic status and mothers' physical activity has been shown due to wide variations in time spent in physical activity within each socioeconomic group.<sup>19</sup> The authors concluded that some mothers, irrespective of their socioeconomic group, were able to overcome constraints to be physically active.<sup>19</sup>

### ***Psychosocial factors of influence***

#### Attitudes

A number of qualitative studies have explored parents' attitudes towards physical activity and their beliefs regarding the outcomes of being physical active. Generally, findings have shown that parents believe that physical activity improves their personal health and fitness,<sup>20</sup> but refer in particular to the benefits for their mental wellbeing.<sup>16,17,128,167,179</sup> These mental health benefits are identified by parents as integral in improving coping mechanisms as a parent, in that by being active they are happier and consequently a better parent.<sup>16,17,20,167</sup> Active mothers also describe how by being active they are providing an important role model for their children.<sup>184,185</sup> On the other hand, there is the belief that to be physically active can add to the stress of being a parent<sup>186,187</sup> and interfere with their parenting responsibilities.<sup>167</sup> In their study of behavioural beliefs and physical activity behaviour among parents of young children, Hamilton and White<sup>169</sup> found two independent beliefs were significant predictors of physical activity behaviour: that

physical activity improves parenting practices (positive predictor), and that physical activity interferes with other commitments (negative predictor).

### Subjective Norms

Social support, in terms of approval and disapproval from others is an important influence of physical activity behaviour. Three qualitative studies have explored this influence in parents of young children.<sup>17,167,188</sup> Approval for physical activity is sought by women with young children from partners, children, other family members, and friends; however Hamilton and White<sup>167</sup> highlighted inherent paradoxes associated with approval from others. Specifically women with young children believed that approval from partners may be granted on the terms that it does not increase their partner's responsibility or workload, and approval from their children was given as long as the activity was integrated with them. Similarly, men with young children believed approval from partners for their physical activity was conditional on its integration with the family and not independent.<sup>167</sup> In some cases, approval and support from partners added to the pressure of motherhood and guilt for not being active.<sup>188</sup> In a study of physical activity beliefs, intention, and behaviour, social support from partners was independently associated with exercise intentions, and support from exercise partners was associated with actual exercise behaviour.<sup>169</sup>

Wider social norms are also important factors influencing parental physical activity, particularly among mothers. A central tenet throughout the mothering and physical activity literature is the ideology of an 'ethic of care', where the needs of children and family are placed above personal needs. Lewis and Ridge<sup>16</sup> aptly explained that although women are aware of the importance of caring for self, the ethic of care associated with socially constructed notions of a 'good mother' makes it difficult to prioritise time for themselves over child and domestic responsibilities. Women frequently describe feelings of guilt, selfishness, and avoidance of responsibility in relation to taking time for personal physical activity.<sup>16,17,20,167,189-191</sup> However, some mothers have described how seeing other parents being physically active helped to lessen their own guilt for engaging in physical activity.<sup>169,186</sup>

There is a clear distinction in the qualitative literature between mothers with a strong ethic of care, and those with a strong sense of entitlement to physical activity and time for self. Two

studies have specifically explored these concepts in groups of active and inactive mothers;<sup>17,189</sup> their findings showed that active mothers had a strong sense of entitlement and made physical activity a priority, even among those with low partner support.<sup>189</sup> These women believed that physical activity was important for their own physical and mental wellbeing and made the necessary trade-off with domestic standards and relinquished feelings of guilt for taking time away from children. On the other hand, inactive mothers displayed stronger levels of ethic of care, where physical activity was considered selfish and took time away from family.<sup>189</sup>

### Perceived Behavioural Control

A critical element linking attitudes and support for physical activity with actual behaviour is perceived control over the ability to perform physical activity.<sup>172</sup> Although parents experience similar constraints to physical activity as non-parents, those with young children are thought to experience a stronger association with these constraints.<sup>192</sup> In particular, lack of time due to child and work commitments,<sup>19,147,167,169,179</sup> tiredness and fatigue,<sup>19,167,179,182,189</sup> and inconvenience<sup>147,167</sup> are significant barriers affecting volitional control over behaviour. The perception of control over being physically active is influenced to a large degree by the responsibilities of parenthood. Inconvenience ( $p < .001$ ) and lack of time due to childcare responsibilities ( $p < .01$ ) have been shown to be significantly associated with parents' intention to be active,<sup>169</sup> and actual physical activity behaviour ( $p < .001$ ) in a sample of men and women with young children.<sup>169</sup> Women with children have also been shown to perceive physical activity during leisure-time as less feasible and physical activity through work or domestic activities as more feasible; strategies suggested by women to make physical activity participation easier included access to inexpensive childcare.<sup>193</sup>

Belief in one's ability to successfully perform physical activity is also related to perceived behavioural control. Three studies have shown that self-efficacy is a strong predictor of stage of readiness for physical activity, with self-efficacy increasing across the stages of behaviour change,<sup>114,182</sup> and the highest levels of self-efficacy were among women in the action and maintenance stages of behaviour change.<sup>142,179</sup> A study investigating exercise self-efficacy and barriers to leisure-time physical activity in new mothers (< 6 month postpartum) found that barrier self-efficacy (confidence in overcoming barriers) significantly predicted leisure-time physical activity.



### ***Environmental factors of influence***

Built environmental influences such as neighbourhood walkability and local destinations have been shown to be independently associated with individual levels of physical activity.<sup>194</sup> To date no studies have explored the interaction between household and environment influences on physical activity of parents with young children, however it is possible that parents with young children may interact with their neighbourhoods differently than adults without children. For example, access to nearby green space, playgrounds, or recreational facilities may provide physical activity opportunities for parent and child physical activity, whereas good transportation networks may be more beneficial for adult commuters. Furthermore, it may be that the built environment is even more influential for those with young children at home, as they may spend more time in their neighbourhood compared with those who travel outside their local neighbourhood for work and non-work activities. Time use data from New Zealand show that 79% of mothers' of their childcare time, and 87% of fathers' childcare time, occurs at home.

Access to nearby green space and playground facilities may provide important destinations for physical activity among those with a young child at home. A study of park use among families with different structures was conducted in Minneapolis, United States, and reported that 46% of two-parent families (with one parent working) visited local parks at least four times per week;<sup>195</sup> the mean age of the youngest child in this family-type was 4.9 years. The nearest park was located on average 320 metres (0.2 miles) from the family residence, and over the 3 days prior to survey, families visited the park on average 1.4 times. Another study observing physical activity of children in parks found that young children (aged 0–5 years) were less likely to have high levels of physical activity during play in more formalised settings.<sup>196</sup> In a study of older children (aged 8 to 14 years), 20% of joint parent and child physical activity (co-occurring between child and parent) occurred in open spaces (e.g., parks).<sup>162</sup> Neighbourhood walkability may also be an important influence on walking behaviours of parents with young children. Indeed, a pram-walking intervention in mothers of young children found that women experienced poor quality footpaths that made pram-walking difficult, and for some mothers absence of footpaths prevented pram-walking altogether.<sup>147</sup> It is clear that much is yet to be understood about how neighbourhoods related to parental physical activity.

## **Summary**

There are a wide range of complex factors that influence parents' physical activity behaviours. Sociodemographic factors are largely unclear, and it is possible that being a parent moderates any effect of marital status, employment status, ethnicity, and socioeconomic status on physical activity behaviour. Family structure, however, may explain some variance in parental physical activity, particularly the age of the youngest child. Perhaps most relevant are the psychosocial factors that influence parents' motivation and intentions to be physically active. While parents largely believe that physical activity is important for their personal health and wellbeing as well as that of their family, they also believe that their parenting responsibilities take precedence. This is largely influenced by subjective norms, including social support from partners, children, and friends, and wider societal norms of an ethic of care. This ethic of care is a central tenet of mothering, where the needs of others are placed above personal needs and feelings of guilt and selfishness arise when time is taken for oneself. There is a clear distinction amongst mothers who are active and those who are not in terms of their sense of entitlement to physical activity and those with a prevailing ethic of care. Furthermore, parents face unique factors of control over their ability to be physically active, regardless of motivation or intention. In particular, lack of time due to responsibility for childcare commitments substantially affects parents' autonomy for participation in leisure-time physical activity. Furthermore, environmental factors, such as the neighbourhood environment, may also act to encourage or prohibit the process between intention to be active and actual behaviour, however little is currently known of these factors in parents of young children. Currently, it is clear that psychosocial factors of influence play a significant role in determining motivation and intention for physical activity that is undertaken for leisure. It is also evident that these factors are largely ingrained in societal norms and expectations of parents, in particular mothers. More understanding is needed of the factors that influence different sources of physical activity; for example, what factors are associated with more or less childcare and household-related physical activity.

## **Benefits of parental physical activity**

Physical activity plays an important role in the preservation of good health and wellbeing among all people, both in the long term and for day-to-day functioning. These benefits are discussed in the physical activity epidemiology section of this chapter, however there are some particularly

salient benefits for parents that deserve further attention. For parents, being physically active not only provides protection against many non-communicable diseases, it also contributes to positive personal and familial wellbeing, and provides beneficial role modelling behaviour for their children.

Being physically active can contribute positively to adults' psychological health;<sup>2</sup> the benefits related to improved energy,<sup>118</sup> overall mood,<sup>1-3</sup> and depressive symptoms<sup>1-4</sup> are particularly salient for parents as fatigue, sleep disturbance, and increased rates of depressive symptoms are common among parents of young children.<sup>197,198</sup> However, the type and context of physical activity may be an important factor for these outcomes, with leisure time physical activity (but not non-leisure physical activity) associated with greater wellbeing<sup>199</sup> and reduced depressive symptoms<sup>4,200</sup> among adults. Several intervention studies among new mothers have shown positive effects of exercise on energy, wellbeing, and depressive symptoms,<sup>155,157,158,201</sup> and both mothers and fathers have described how exercise improves their energy levels and wellbeing in qualitative studies.<sup>16,169,197</sup> However, no studies have investigated the psychological effects of non-leisure physical activity among parents.

Several mechanisms through which physical activity benefits psychological health have been proposed, including physiological and neural pathways, neuroplasticity via hormetic stress response function,<sup>202</sup> diversion from negative thoughts, and through positive social interactions.<sup>200</sup> Understanding gained from qualitative research suggests that for parents independent physical activity provides an opportunity for time away from childcare and household responsibilities, which may be an important contributing factor to these benefits.<sup>17,20,187</sup> However, other studies have reported positive outcomes of exercise whether undertaken independently or with their child.<sup>157,184</sup> Greater understanding is required of the type and dose of physical activity required to improve mood, increase energy, promote good sleep, and reduce depressive symptoms among parents.

Qualitative studies have also shown that parents believe that being physically active contributes to the wider wellbeing of their family unit, through strengthened relationships and improvement in their parenting practices. Mothers of young children have reported that being active with their families provides an opportunity for positive shared family time which strengthens relationships and provides an active family lifestyle;<sup>16,20</sup> a finding that has also been shown for families with

older children.<sup>203-205</sup> Shared participation not only encourages healthy relationships, it also provides opportunity for children to participate in physical activity. Furthermore, some parents describe how physical activity enables them to be better parents which is likely to result from increased energy, time out from responsibilities, and stress relief of independent physical activity.<sup>16,17,20,185</sup> These benefits to the wider family unit may be particularly valuable for parents as they reconstruct their physical activity in view of their responsibilities to others.

A physically active parent is also an important correlate of children's physical activity. Parents are principal role models for their children across all aspects of living, and physical activity participation is no exception. Previous research has shown that parental participation in physical activity is significantly associated with their own young children's physical activity rates.<sup>21-23</sup> Furthermore, parental beliefs of the value of physical activity underscore opportunities and encouragement for their children to engage in physically active pursuits.<sup>206-209</sup> Globally, children aged < 5 years are recommended to accumulate at least 60 min of structured and unstructured physical activity every day,<sup>210</sup> to achieve benefits including maintenance of healthy body size, bone density, and improved fundamental motor skill development.<sup>211</sup> Parents are central agents for children's physical play opportunities and it is likely that physically active parents will be more favourable towards provision of time, equipment, and resources required for children to achieve these recommendations.

These benefits are particularly relevant for parents of young children and encourage physical activity to be undertaken in a range of contexts. Independent physical activity may deliver important psychological outcomes for parents, particularly via time out from parenting responsibilities, but also provides important role modelling behaviour for their children. Leisure activity that is integrated with the family creates opportunities for children and parents to be physically active and contributes towards an active family lifestyle. In addition, family relationships may be strengthened through shared participation.

## **Summary**

Understanding of adult physical activity during the period of early parenthood is a relatively neglected aspect of physical activity epidemiology. Since the 1990s studies have documented a link between parenthood and low participation in physical activity, however this association was

not included among the correlates and determinants of adults' physical activity presented in a recent review.<sup>54</sup> While the methodological quality of parent studies are varied, there is consistent evidence to indicate that parents are less active, in leisure-time, than non-parents. There is also some evidence to suggest that parents have lower levels of sedentary behaviour and higher levels of household and childcare-related physical activity. A number of qualitative studies have explored the underlying reasons why parents are less active than non-parents which consistently show that psychosocial factors play an integral role in parents' decisions to participate in leisure-time physical activity. Wider social norms of an ethic of care, where mothers relegate their own needs for those of others, are especially relevant as mothers do not prioritise time for themselves and feelings of guilt and selfishness arise when mothers do. Other factors also play an important role, including the age of the youngest child, social support from significant others, and perceived control over time and responsibilities.

A number of questions remain unanswered. More understanding is needed of how different sources of physical activity track across the transition to parenthood and over time as the youngest child ages. There is a dearth of research investigating physical activity among fathers, including non-leisure sources and the factors influencing fathers' physical activity levels. There is also a lack of understanding how parents of young children interact with their local neighbourhood, and whether these interactions differ from adults without children. Furthermore, there is a substantial gap in knowledge of the volume and patterns of physical activity across the intensity spectrum, and in particular sedentary behaviour. Future research would be enhanced through use of objective measurement tools to quantify time spent being physically active and sedentary, and to understand the nature of how this time is accumulated.

## **Chapter conclusions**

The body of knowledge pertaining to physical activity in parents with young children is largely based on exercise and leisure sources of physical activity. It is well documented that parents face unique constraints over their autonomy for physical activity and have limited opportunity to engage in planned and purposeful activity. On the other hand, it is likely that taking care of young children offers plentiful opportunities for physical activity to be a major part of everyday living although the full extent of these opportunities remains unclear. Parenthood is a life stage that provides an ideal case to consider whether current public health messages promoting a

one-size-fits-all approach to physical activity is appropriate. The series of studies that follow provide a starting point for investigating and understanding different profiles of physical activity behaviour, and exploring what this may mean for public health. In order to advance the field of epidemiology, the totality of physical activity needs to be addressed and this may be further enhanced by placing this within the context of daily patterns of living for different types of people.

# **Measuring physical activity and sedentary behaviours in women with young children: A systematic review**

## **Preface**

The overarching aim of this thesis is to describe in detail the amounts and patterns of physical activity and sedentary time undertaken by adults who have young children at home. A review of the literature identified that women with young children were consistently reported to be at risk of insufficient activity for health. However, some studies questioned whether these reported findings misrepresented the true amount of physical activity accumulated by those with young children because of issues with measurement issues. Specifically that of accurately assessing overall amount and different types of activity in this population. The purpose of this chapter is to review and critique the methods of physical activity measurement that have been employed in previous studies of physical activity in women with young children. This review examines the methods employed and the potential effect of these methods on physical activity prevalence outcomes, outlines measurement issues for studying this population, identifies gaps in current knowledge, and outlines directions for future research. Findings from this study identified a significant gap in knowledge that subsequently formed the development of the thesis study design and synthesis of the research questions. The manuscript resulting from this chapter was published by the peer-reviewed journal, *Women and Health*.

## **Abstract**

Current evidence indicates that women with young children are less active than women without children. This review investigated the methods of measuring physical activity employed in studies of women with young children (aged 1–5 years) and the associated measurement issues. Articles sourced from databases (MEDLINE, OVID, CINAHL, and Google Scholar) and manual searches were limited to English peer-reviewed journals published from 1990 to 2010. Studies that included measurement of physical activity in samples of women with young children were selected. Measurement properties were extracted, and original reliability and validity papers were reviewed for physical activity measurement tools used by 15 independent samples. The current evidence base is heavily dominated by self-report measurement tools, many of which assess leisure-time physical activity only. Use of motion sensors to assess physical activity among this population was severely limited. It is highly likely that much of the habitual physical activity performed by women with young children is not being captured by self-report measures. Further investigation should be undertaken using tools that adequately capture all health-enhancing physical activity among women with young children.



## Introduction

It is well documented that physical activity is beneficial for maintaining health and quality of life. The benefits of regular physical activity for women's health and well-being are extensive, including the prevention of cardiovascular disease, diabetes and some cancers.<sup>212</sup> In the short term, attaining recommended levels of physical activity can improve quality of life<sup>213-215</sup> and reduce likelihood of sleeping difficulties, back pain, tiredness, and depressive symptoms among women.<sup>118,200,201,216,217</sup> Furthermore, the benefits of leading a physically active lifestyle extend beyond the individual to the family unit; being physically active with partners and/or children may positively influence familial relationships while providing important active role models for children.<sup>16</sup> Indeed, parental physical activity has been positively associated with physical activity levels of young children.<sup>21</sup> Despite these particularly pertinent benefits, Bellows-Riecken and Rhodes<sup>118</sup> review of physical activity in parenthood showed that women with young children (WYC) were less active than their childless counterparts. Longitudinally, physical activity has been shown to decrease during the transition to motherhood<sup>121,122,124</sup> and does not return to original levels.<sup>18</sup>

A great deal of literature has focused on physical activities performed by the general adult population, however, WYC might differ significantly in the way they accumulate daily physical activity. The most signifying element of WYC is their role of responsibility. Essentially, this responsibility places boundaries around the freedom of choice of daily and leisure-time activities. While an adult is caring for a child it is possible for them to perform other tasks, yet they are severely constrained in the choice of these activities.<sup>94</sup> Activities tend to be more intermittent, less structured, concurrent, and of light-to-moderate intensity.<sup>111,154</sup> During times when an adult is relieved of immediate childcare responsibility, qualitative research has shown that mothers continue to feel constraint in the legitimate use of their time, with the feeling that time belongs to others.<sup>218</sup> This role of responsibility has the potential to severely affect the time available to participate in physical activity at recommended levels sufficient for health benefit. Women in the postnatal period with children aged < 12 months may experience further constraints upon their time with significant time demands for feeding and caring for a dependent baby.<sup>219</sup> For all WYC, overall daily energy expenditure is likely to be a sporadic accumulation of light-to-moderate intensity activity, rather than planned continuous bouts of MVPA. Current

World Health Organization<sup>42</sup> recommendations state that health may be improved through participation in at least 150 min of moderate-intensity or at least 75 min of vigorous-intensity aerobic activity throughout a week (or an equivalent combination of moderate- and vigorous-intensity activity). In addition, muscle strengthening activities should be completed on two or more days a week. These recommendations include activities performed during leisure time physical activity, transportation, occupation, household chores, play, games, sport and planned exercise. In an Australian sample of WYC aged 5 years and younger, more than 64% reported less than 150 min of active leisure per week.<sup>19</sup> Similarly, United States intervention participants reported pre-test mean of  $70 \pm 36$  min of physical activity per week.<sup>140</sup>

Meanwhile, interest is growing in the health benefits of all non-sedentary behaviors,<sup>151,220,221</sup> and conversely, the poor health outcomes of sedentary behaviors such as sitting.<sup>32,71,72,222</sup> Recent evidence has shown that significant energy may be expended in activities such as free-living walking or short bouts (< 15 min) of low-velocity (~1 mph) walking.<sup>220</sup> Further, early indications show sitting time has an independent association with mortality rates from all causes and cardiovascular disease.<sup>32</sup>

Despite current evidence indicating that WYC are less active than their childless counterparts, comprehensive information is lacking about the patterns of habitual physical activity that WYC accumulate and the time this population spends in sedentary pursuits. It is important to consider the contribution physical activity in non-leisure domains (e.g., household, transport) make to the overall physical activity of WYC. Application of self-report tools among WYC may be problematic; many self-report tools inadequately capture physical activities in non-leisure domains and among adult populations have been shown to misrepresent total activity as measured by objective measures (accelerometer and pedometer).<sup>58,223</sup> This effect may be more pronounced among WYC, given the likelihood that a significant amount of time is spent in sporadic, concurrent, and unstructured activities.

Recently, researchers have developed interest in the complexities of measuring physical activity amongst WYC, and a range of measures have been utilized. Whilst efforts have been made to develop measures that capture physical activity and inactivity across the spectrum, this area of measurement research is still in its infancy. In order to accurately understand prevalence, health outcomes, and moderators of physical activity in WYC, it is critical that measurement tools

employed in this population appropriately capture this broad spectrum of active and inactive behaviors.<sup>72,75</sup>

The purposes of this review were to: (1) investigate the methods that have been used to assess physical activity in WYC, (2) identify the potential effect of differing methods on prevalence data, (3) outline physical activity measurement issues specific to this population, and (4) suggest how measurement methodology may be refined to better understand the physical activity behaviors of WYC.

## Methods

Computer searches (MEDLINE, OVID, CINAHL, and Google Scholar) and manual searches were conducted of articles in English language literature from 1990 to June 2010. Keywords included: 'physical activity', 'exercise', 'leisure', 'recreation', 'sedentary', 'measure', 'accelerometer', 'survey', 'self-report', 'valid', 'reliable', 'pedometer', 'parent', 'mother', 'women', 'dependent', 'child'. Search terms included a combination of keywords, for example 'physical activity' AND ('measure' OR 'self-report', OR 'accelerometer' OR 'pedometer') AND ('mother' OR 'parent'). Only published articles in refereed journals and manuscripts accepted for publication in refereed journals were considered for this review. Studies that assessed physical activity in samples of WYC (children aged 1–5 years), or in which a physical activity measurement tool was assessed with WYC were included. Articles focusing on the immediate postpartum period (0–12 months) were excluded as this life stage has significantly unique characteristics and subsequent constraints on maternal activity; however, studies were considered if the sample included both children aged < 12months as well as 1–5 years. Similarly, studies that included both children aged 1–5 years and children aged > 5 years were considered in this review. Physical activity measurement tools were defined as those that assess physical activity frequency, duration, and/or intensity; tools that assessed fitness attributes, such as maximal oxygen uptake (VO<sub>2</sub> max) or flexibility, were excluded. Measurement properties of physical activity tools (construct, domain, recall, parameters, format, items, score, unit), sample characteristics, and key activity findings were extracted from included studies, and original reliability and validity papers were sourced and reviewed for measurement tools used by independent studies.

## Results

Of the 18 studies included in this review, 15 were from independent samples. Two studies used the same sample of WYC enrolled in the Moms on the Move intervention in the United States;<sup>140,176</sup> two studies analyzed a sample of WYC participating in an intervention trial;<sup>120,135</sup> and two studies analyzed a sample of 1,113 Canadian women.<sup>98,117</sup> Reference hereafter will be made to the measurement tools used in the independent samples ( $n = 15$ ). Twelve studies assessed physical activity in samples of WYC, while six studies analyzed data from a sub-sample of WYC drawn from larger women's or adult studies. The overwhelming majority of studies were cross-sectional, had small samples, were published after 2003, and used self-report measures of physical activity. Seven studies specifically considered mothers of preschool children (aged < 5 years), whilst the remaining studies included mothers of children across the age spectrum of 0–18 years (Table 4).

### Self-reported physical activity

Self-report measures of physical activity dominate the literature with fourteen independent samples using varying forms of interviewer-administered or self-administered questionnaires. The current review identified three key self-report instruments used by nine independent studies: 7 day PAR, Godin Leisure-Time Exercise Questionnaire (LTEQ), and the Australian Women's Activity Survey (AWAS). Of the remaining studies, two drew data from large national studies<sup>177,178</sup> and one from a birth cohort study,<sup>201</sup> for which physical activity questions were a subsection; and two independent studies modified questions from national physical activity questionnaires.<sup>19,120,135</sup>

**Table 4.** Methodological attributes and key activity findings of included studies

Measure Tool Reference	Year	Study Design	Sample ( <i>n</i> ; mean age or range)	Sample Characteristics	Age of children	Key Activity Findings
<b>Self-report:</b>						
1994 NSW Health Promotion Survey:						
Brown, Brown, Miller, & Hansen <sup>19</sup>	2001	Cross-sectional	554; 33 y	Mothers	≤ 5 y	> 66% mothers reported < 150 min active leisure/week.
Active Australia – Modified:						
Brown, Miller, & Miller <sup>120</sup> <sub>a</sub>	2003	Cross-sectional	529; 18–64 y (mothers) 185; 18–64 y; 60% female (workers)	Separate sample mothers and 'workers'	< 5 y 5–18 y	Mothers participate in less physical activity than a sample of workers. No physical activity 14.1%; 11.9%, respectively ( $p < .05$ ) < 150 min/week 37.2%; 28.6%, respectively ( $p < .05$ ) > 150 min/week 48.7%; 59.5%, respectively ( $p < .05$ )  Mothers spend less time sitting per day than sample of workers 3.5 ± 2.20 and 9.4 ± 2.40 hr, respectively.
Miller, Trost, & Brown <sup>135</sup> <sub>a</sub>	2002	Intervention	554; 32.8 y	Mothers	< 2 y ≤ 5 y	At follow-up, intervention groups were more likely to meet current guidelines. Control 46.3% Intervention 1 50.4% Intervention 2 59.9%

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 Australian Women's  
Activity Survey:

Fjeldsoe, Marshall, & Miller <sup>146</sup>	2009	Reliability and Validity	40; 33 y reliability protocol 75; 32 y validity protocol	Mothers	≤ 5 y	Women participate in 180 ± 361 min HEPA/week.
Godin LTEQ:						
McIntyre & Rhodes <sup>128</sup>	2009	Cross-sectional (retrospective)	139; 31.2 y	Mothers	0–4 y	Weekly exercise decreased after becoming a parent. Before parenthood: 249.74 ± 209.62 min/week total physical activity After parenthood: 169.89 ± 184.53 min/week total physical activity $F = 17.05$ ( $p < .01$ )
Tavares, Plotnikoff, & Loucaides <sup>114</sup>	2009	Cross-sectional	302; 41 y (Mothers) 881; 46 y (non-mothers)	Occupational women	< 13 y	Women with children less 'active' (≥600 METs/week) than women without children (54% and 58% respectively). Weekly EE was lower for women with children (587 ± 688.24 METs) than women without children (647 ± 704.36), $t = -1.27$ ( $p < .21$ )
Verhoef & Love <sup>117 c</sup>	1992	Cross-sectional	1,113; 20–49 y	Women's study, mothers 56.2%	< 17 y	49.0% and 61.8% mothers and non-mothers exercise, respectively ( $p < .001$ ). 20.8% and 37.2% mothers and non-mothers are very active (≥90 min/week), respectively ( $p < .001$ ).

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Verhoef & Love <sup>98 c</sup>	1994	Cross-sectional	1,113; 20–49 y	Women's study, mothers 44%	< 17 y	Mothers participate in less strenuous and moderate activity than non-mothers. Strenuous 28.6%; 44.4% ( $p < .01$ ) Moderate 55.1% ; 68.8% ( $p < .01$ ) Mild 64.4%; 66.3% ( $p > 0.01$ )
National Population Health Survey, Canada:						
Young, James, & Cunningham <sup>178</sup>	2004	Cross-sectional	2,184;	Sub-sample of mothers drawn from national study	< 18 y	No differences in physical activity between lone and partnered mothers, 45.3% and 41.4% 'active', respectively ( $p \geq 0.05$ ).
Parent 1 Self-complete Questionnaire, Australia:						
Craike, Coleman, & MacMahon <sup>201</sup>	2010	Cross-sectional	4,702; 34.6 y	Mothers of infants cohort	3–19 months	Mothers participate in $2.77 \pm 1.89$ (range 0-7) days physical activity $\geq 30$ min/week.
7 day PAR						
Fahrenwald & Walker <sup>182</sup>	2003	Cross-sectional	30; 24.33 y	Mothers	Dependents	Stage of change was significantly related to min of moderate to very hard physical activity ( $r_s = .81$ , $p < .01$ ). Pre-contemplation ( $n = 6$ ), $2.85 \pm 4.78$ min/day Contemplation ( $n = 6$ ), $6.07 \pm 6.75$ min/day Preparation ( $n = 6$ ), $10.47 \pm 7.25$ min/day Active ( $n = 6$ ), $42.50 \pm 21.37$ min/day Maintenance ( $n = 6$ ), $37.26 \pm 20.62$ min/day

Fahrenwald, et al. <sup>140 b</sup>	2004	Intervention	44; 26.5 y	Mothers	Dependents	<p>The experimental group significantly increased moderate physical activity (<math>p &lt; .001</math>, <math>d = 2.07</math>).</p> <p>Study sample pre-test mean = <math>70.00 \pm 35.93</math> min/week</p> <p>Experimental group mean change = <math>88.18 \pm 45.94</math> min/week</p> <p>Control group change mean change = <math>1.14 \pm 38.05</math> min/week</p>
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Fahrenwald, et al. <sup>176 b</sup>	2005	Intervention	44; 26.5 y	Mothers	Dependents	Prevalence not reported.
Fahrenwald & Shangreaux <sup>179</sup>	2006	Cross-sectional	30; 21.3 y	Mothers	Dependents	Among sample of American Indian mothers, stage of change was significantly related to min of moderate to very hard physical activity ( $r_s = .74$ , $p < .01$ ). Pre-contemplation ( $n = 6$ ), $2.85 \pm 4.78$ min/day Contemplation ( $n = 6$ ), $6.07 \pm 6.75$ min/day Preparation ( $n = 6$ ), $10.47 \pm 7.25$ min/day Active ( $n = 6$ ), $42.50 \pm 21.37$ min/day Maintenance ( $n = 6$ ), $37.26 \pm 20.62$ min/day
Sallis, et al. <sup>133</sup>	2001	Longitudinal	226; 31-32y	Mothers	4y	European-American mothers reported more vigorous leisure ( $p < .005$ ), but less moderate work ( $p < .02$ ) than Mexican American mothers. There were no differences in moderate leisure ( $p < .91$ ) or vigorous work ( $p < .13$ ) activities.
Urizar, et al. <sup>224</sup>	2005	Intervention	68; 31.7y	Sub-sample of mothers drawn from women's study	$\leq 5y$ 6-18y	Mean baseline physical activity $32.9 \pm 1.3$ kcal.kg-1.day-1 Mothers significantly increased energy expenditure from baseline to 10-weeks ( $t = 2.36$ , $p < .05$ ).
U.S. National Health and Nutrition Examination Survey III:						
Young, Cunningham, & Buist <sup>177</sup>	2005	Cross-sectional	1,446; 17-59y	Sub-sample of mothers drawn from national study	$< 17y$	More lone mothers participate in $\geq 20$ bouts ( $\geq 30min$ ) of physical activity per month than partnered mothers; 35.8% and 29.9% respectively.

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**Pedometer:**

Yamax Digi-walker SW-200:

Fahrenwald, et al. <sup>140</sup>	2004	Intervention	11; 26.5y	Mothers	Dependents	The experimental group increased mean daily step counts from pre-test (5,825 ± 1,847 steps) to post-test (9,181 ± 1,700) ( $t = 6.16$ , $p < .001$ ).
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Yamax Digi-walker SW-701:

Clarke, et al. <sup>142</sup>	2007	Intervention	124; 18-45y	Mothers	1-4y	Low-income women increased mean daily step counts from baseline (5,969 ± 3,123) to post-test (9,757 ± 3,843). At baseline, 11.8% participants achieved ≥10,000 steps/day, increasing to 46.2% at post-test.
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**EE** = Energy expenditure, **METs** = Metabolic equivalents, **y** = Years

<sup>a</sup> Brown, et al.<sup>120</sup> and Miller, et al.<sup>135</sup> use same dataset for analysis

<sup>b</sup> Fahrenwald, et al.<sup>140</sup> and Fahrenwald, et al.<sup>176</sup> use same dataset for analysis

<sup>c</sup> Verhoef & Love<sup>117</sup> and Verhoef & Love<sup>98</sup> use the same dataset for analysis

**Table 5.** Measurement properties of self-report tools

Tool	Construct				Format			
	Dimension	Domains	Recall period	Parameters	Administration	No. of items/time to complete	Scores	Unit of measurement
1994 NSW Health Promotion Survey	PA	L, O, T	Previous 7 days	D, I	Self-administered	?	Total	Min/week
Active Australia -modified	PA	L, T, St	Previous 7 days	F, D (> 10min), I	Self-administered	24	TEE	MET.min/ week
Australian Women's Activity Survey	PA	P, H, O, T, C, St	Usual 7 days	F, D, I	Interview	67	Total - P, H, O, T, C; Total - Sitting, light, walking, moderate, vigorous; Total activity Total HEPA (w+m+v)	Min/week
Godin LTEQ	Exercise	E	Usual 7 days	F (> 15min), I	Self-administered	4	Total, light, moderate, strenuous	Times/week
Parent 1 Self-complete Questionnaire, Australia	LTPA	L	Usual 7 days	F > 30min	Self-administered	1	0-7	Days
National Population Health Survey, Canada	LTPA	L	Previous 3 months	F, D	Interview	?	TEE	Kcal/kg/day

7 day PAR	PA	Sp, H, O, S, [St]	Previous 7 days	F, D (> 10min), I	Interview	~20 min	Sleep, [sitting], Light, moderate, hard, very hard	Min/week
U.S. National Health and Nutrition Examination Survey III (1988-1994)	LTPA	L	Previous month	F	Interview	?	Leisure activities	Frequency/month

C = Childcare, D = Duration, E = Exercise, F = Frequency, H = Household, I = Intensity, L = Leisure, LTPA = Leisure-time Physical Activity; Kcal = Kilo calories, MET = Metabolic equivalent, O = Occupational, P = Planned activities, PA = physical activity, R = Recreation, S = Sleeping, Sp = Sport, St = Sitting, Sg = Strength exercises, T = Transport, [x] = modified version, ? = unknown

### ***Content Validity***

Content validity refers to the appropriateness of the tool to measure the construct in question. In this case, the construct refers to overall daily physical activity, which may be undertaken in all domains, including occupation, transport, household, leisure and planned exercise.<sup>42</sup> Leisure-time, sport, and exercise activity dominated the measurement tools employed in WYC samples (Table 5). Less than half the instruments additionally captured physical activity performed in other domains, including occupational ( $n = 3$ ), transportation ( $n = 3$ ), household ( $n = 2$ ), sitting ( $n = 2$ ), sleeping ( $n = 1$ ), and childcare ( $n = 1$ ). The AWAS and PAR provided the most comprehensive assessment of physical activity across the spectrum, with the inclusion of leisure-time, household, occupational, transportation, and sitting time. The AWAS also captured childcare activity, and the PAR considered sleeping time. Further, the AWAS and PAR were the only included studies to be interviewer-administered. The majority of tools captured activity across a seven-day period, with a mix of previous week ( $n = 3$ ) and usual week ( $n = 3$ ) activity. With the exception of four tools, physical activity was scored by duration of activity over the recall period, including total minutes, MET-minutes, and minutes per domain or intensity. Other scores included frequency of participation and total energy expenditure (kilocalories per kilogram per day).

### ***Reliability and Concurrent Validity***

Original reliability and validity studies were sourced for the three key instruments included in this review, and data pertaining to the sample, comparison measures, reliability and validity were extracted from these studies (Table 6). The Godin LTEQ was validated using VO<sub>2</sub> max and body fat; findings showed that strenuous activity was more accurately reported than mild or moderate activity. Similarly, an investigation of test-retest reliability of the Godin LTEQ in a sample of 53 adults also showed strenuous activity was more reliably reported than light and moderate activity.<sup>225</sup> The PAR has been validated for use in numerous populations, including children and adults. Recently, Wilkinson and colleagues<sup>139</sup> validated the PAR in a sample of 3-month postpartum women using pedometer steps. Using the Welk algorithm,<sup>226</sup> minutes spent sitting were negatively correlated with pedometer step counts, and minutes spent in light activity and total activity (sum of light-to-very hard activity) were significantly positively correlated with step counts. The authors concluded that obtaining time spent sitting, and extracting this from

light activity, may improve the validity of PAR estimation of activity in low-income postpartum women.

Additionally, Johnson-Kozlow et al.<sup>227</sup> compared the agreement of the PAR and another 7 day recall tool (IPAQ) with accelerometer data in a sample of breast cancer patients ( $n = 159$ ) and concluded the PAR instrument was superior to the IPAQ in all respects (measurement bias, criterion-related validity, specificity, sensitivity, and agreement). Lately, the AWAS was developed following a systematic review and qualitative exploration of physical activity behaviors of WYC. Data showed the tool provided a reliable measure of physical activity in this population, across all active intensities (ICC = 0.66–0.80), but a lower intraclass correlation coefficient was found for sitting time (ICC = 0.42). The AWAS was validated using MTI accelerometer data collected during a 7 day period prior to survey completion. Spearman correlation coefficients were weak across all activity domains (planned, transport, occupational, household, childcare) at each intensity level ( $r_s = .06-.13$ ), although a moderate association was found for sitting time ( $r_s = .32$ ). Moderate and vigorous activity in the planned and transport domains showed coefficients comparable with other self-report tools used among the general population ( $r_s = .22-.36$ ).<sup>146</sup>

### **Motion sensors**

No studies incorporated accelerometers in their measurement methodology, and only two studies assessed physical activity using pedometers (Table 4). Pedometers are small hip-worn devices that quantify physical activity by capturing all ambulatory activity in terms of accumulated steps. Clarke et al.<sup>142</sup> employed the Yamax Digiwalker SW-701 to evaluate the effectiveness of an intervention to increase physical activity among overweight and obese low-income mothers. Fahrenwald et al.<sup>140</sup> assessed physical activity with the Yamax Digiwalker SW-200 at baseline and post-intervention in a sub-sample of WYC participating in an intervention to increase physical activity. Both pedometer models have been validated in a number of studies, which have collectively concluded the Digiwalker SW-701 and SW-200 to be among the most accurate pedometers for assessing steps in adult samples.<sup>228-231</sup>

**Table 6.** Reliability and validity of self-report measures

Tool Reference	Reliability			Validity		
	Sample ( <i>n</i> ; mean age or range)	Interval	Results	Sample ( <i>n</i> ; mean age or range)	Comparison measure	Results
7 day PAR						
Sallis 1985	31 <sup>m</sup> , 33 <sup>f</sup> ; 38 y	2 week	Vigorous $r = .83^{***}$ Moderate $r = .75^{***}$	-	-	-
Wilkinson, Huang, Walker, Sterling, & Kim, 2004	-	-	-	44 <sup>f</sup> ; 22.4 y 3-month postpartum women	Yamax Digi-walker (SW-200)	Sleep $r = .07$ Sitting $r = -.45^{**}$ Light $r = .35^*$ Moderate $r = .14$ Hard $r = .12$ Very Hard $r = -.10$ Total (L, M, H, VH) $r = .40^{**}$
Johnson-Kozlow, Sallis, Gilpin, Rock, & Pierce, 2006	-	-	-	159 <sup>f</sup> ; 56.6 y	Actigraph (MTI) 7164	Total activity $r = .73^{***}$ Kappa $k = .59$
Godin LTEQ						
Godin & Shephard, 1985	53;	2 week	Light $r = .48^*$ Moderate $r = .46^*$ Strenuous $r = .94^*$ Total $r = .74^*$ Sweat $r = .80^*$	163 <sup>m</sup> , 143 <sup>f</sup> ; 18-65 y	Maximum oxygen consumption (VO <sub>2</sub> max) [Body fat]	Light $r = .04$ [0.06] Moderate $r = .03$ [0.06] Strenuous $r = .38^*$ [.21*] Total $r = .24^*$ [.21*] Sweat $r = .26^*$ [.21*]

<sup>f</sup> = female, <sup>m</sup> = male, H = Hard, ICC = Intraclass correlation coefficient, L = Light, M = Moderate,  $r$  = Pearson correlation coefficient,  $r_s$  = Spearman correlation coefficient, VH = Very hard, y = Years,  $^*p < .05$ ,  $^{**}p < .01$ ,  $^{***}p < .001$ .

## Prevalence

Due to the small sample of included studies and large variability in methodology and measures, conducting a meta-analysis of prevalence findings according to measurement attributes was not possible; however, no key patterns emerged between tools of similar attributes. Key activity findings from included studies showed that WYC were less active than women without young children and were less active than they were prior to parenthood (Table 4). Further, greater discrepancies between 'mothers' and 'non-mothers' occurred at higher intensities; 28.6% 'mothers' and 44.4% 'non-mothers' engaged in strenuous activity ( $p < .01$ ).<sup>98</sup> A study comparing a sample of WYC with a sample of 'workers' found fewer WYC met guidelines for  $\geq 150$  min moderate- and vigorous-intensity physical activity than 'workers' (48.7%; 59.5%, respectively;  $p < .05$ ). Conversely, WYC spent significantly less time sitting than 'workers', almost 6 hr fewer per day.<sup>120</sup> Significant variations in physical activity levels among WYC were observed across studies, evident through wide standard deviations and variations between studies. Furthermore, WYC in the active and maintenance phases of the Trans-theoretical Model of behavior change exceeded current guidelines, while women in the pre-contemplation, contemplation, and preparation phases showed sequential increases in moderate to very hard physical activity through the model.<sup>179,182</sup> Irrespective of these variations, most studies showed that many WYC participate in less than the recommended level of  $\geq 150$  min physical activity per week.

## Discussion

This review has provided an overview of the methods employed to measure physical activity in studies of WYC. The current evidence base is heavily dominated by self-reported physical activity behaviors, with over 90% of studies incorporating questionnaires in their methodology. A surprising absence of motion sensors to measure activity was noted, considering their current popularity in this field. Of the studies included in this review, two interviewer-administered instruments provided the most comprehensive assessment of physical activity, the PAR and AWAS; however, many tools assessed only leisure-time physical activities. Two measurement tools have undergone validation testing for use in samples of WYC (PAR, AWAS). Due to inconsistencies in measurement methodologies across studies, it was not possible to determine any effects on prevalence data according to the measurement properties of instruments.



To assess physical activity accurately, an instrument must be appropriate to measure the types of activities routinely performed. WYC had low participation levels in leisure-time physical activity, especially at vigorous intensities; yet, time spent in household and childcare activities are much higher than the rest of the population, and sedentary behavior lower.<sup>94,111,120,232</sup> International guidelines recommend physical activities may be performed in the context of daily, family, and community activities for leisure, transport, occupation, household, play, games, sports and planned exercise.<sup>42</sup> It is important to consider the contribution that household and childcare activities among WYC may make to daily energy expenditure and the potentially consequential reduction of sedentary behaviors. Weller et al.<sup>151</sup> examined the relation between physical activity and mortality among a cohort of Canadian women, specifically the impact of excluding non-leisure energy expenditure on this relationship. The authors reported that the inverse relationship between physical activity and mortality was primarily due to the energy expended in non-leisure activities (household chores), representing 82% of total activity among women. They further emphasized the importance of including assessment of household and occupational activity in measures of physical activity. Moreover, Brown et al.<sup>153</sup> measured the energy cost of some activities regularly performed by WYC using indirect calorimetry. Their findings showed that many of these tasks (including vacuuming, washing windows and walking with and without a stroller) are performed at a moderate intensity (3–6 METs), equivalent to a brisk walk. Consequently, the authors proposed the ideal measure of physical activity among WYC would capture inactivity and physical activity across the spectrum in all domains of activity (leisure, occupational, transport and household).

Following a comprehensive review of the literature and qualitative research on the physical activity behaviors of WYC, the AWAS was developed to provide a comprehensive tool to capture physical activity across a wide range of health-enhancing activities, including planned and transport activities, household, occupational and childcare duties.<sup>146</sup> As a result, this tool currently provides the most content-relevant assessment of behaviors routinely performed by WYC. However, only the planned and transport activity domains reported acceptable validity ( $r_s = .22-.36$ ).<sup>146</sup> It is likely the weak Spearman correlation coefficients when including household, occupational and childcare domains were due to complexities of behavior recall. Self-report measures misrepresent physical activity among adults,<sup>58,223</sup> and this effect is most likely to be further evident in populations such as WYC in whom activities are frequently intermittent,

simultaneous and unstructured. It is possible, therefore, that prevalence data determined from current self-report tools may misclassify WYC as insufficiently active for good health.<sup>19,154</sup> While self-report measures do not provide accurate estimates of absolute physical activity, they are useful for measuring a wide range of variables, and importantly, facilitating greater understanding of contexts and patterns of physical activity than objective measures.<sup>233</sup>

Despite the widespread use of objective motion sensors in physical activity epidemiology, only two studies assessed activity with pedometers. Both of these studies employed pedometers to assess physical activity change in response to interventions to increase active behaviors. Although some studies of children's physical activity have used accelerometers in parental assessments of activity, parental activity was not an outcome variable and as such these studies were outside the scope of this review.<sup>21,22,234</sup> The ability of accelerometers (and some pedometers) to capture temporal movement data objectively throughout a given measurement period allows intermittent and brief periods of activity to be recorded, whereas these periods are likely to be overlooked by self-report tools. Motion sensors providing temporal activity data would, therefore, provide useful evidence of the patterns of the intermittent behavior of WYC, something that is absent in the present literature. Accelerometers do have several limitations. Treatment of accelerometer movement counts to interpret intensity of activities varies significantly amongst studies according to the algorithms employed, consequently making cross-study comparisons difficult.<sup>83</sup> Commonly accelerometers are hip mounted and may fail to detect upper body movements, loading, or changes in posture. These variables may be significant to consider in WYC as they may frequently pick up and carry a child for brief or extended periods. The energy cost of this behavior is likely to vary significantly according to the age and weight of the child; however, to the authors' knowledge this is presently unknown. The energy cost of standing, sitting and lying also varies and neither pedometers nor accelerometers presently enable the differentiation between these behaviors. Recently, inclinometers have been used in physical activity research to measure time spent sitting, standing and walking (e.g., Lanningham-Foster et al.<sup>235</sup> and Oliver et al.<sup>236</sup>). Inclinometers are worn on the upper thigh and measure tilt angles. These devices have the potential to provide a useful measure of incidental activities and time spent in sedentary pursuits, and further work is needed to validate them among WYC. Inclusion of self-report measures such as time-use diaries in conjunction

with temporal motion sensors (accelerometers or inclinometers) may be a novel way of gaining understanding of how WYC move and their patterns of activity.

Limitations of this review include the lack of variability and small sample size of included studies, resulting in the inability to perform a meta-analysis of results by measurement method. Additionally, due to the broad nature of search terms (e.g., women, mother, child, physical activity) it is possible that not all eligible studies were retrieved and included.

It is clear from this review that the current evidence base for the prevalence, health outcomes, and moderators of physical activity among WYC is heavily based upon self-reported leisure-time activity. Given well-established benefits of physical activity may be gained from performing physical activity in other domains, future research should endeavor to employ methods that will be sensitive to the unique patterns and contexts of activity of this population. WYC experience difficulties in categorizing and reporting activity frequency and duration,<sup>154</sup> possibly due to the intermittent and unstructured nature of activities. With this in mind, a tool must firstly capture the intermittent nature of activities performed by WYC. Secondly, a tool must measure a broad spectrum of domains and intensities to represent the habitual active living of this population. Third, investigation into the energy cost and muscle strengthening effects of upper body movements associated with carrying children may highlight the need for measurement of these behaviors. Fourth, consideration must be given to measuring sedentary behaviors, as their relative absence in WYC indicates its possible replacement with light-to-moderate intensity behaviors. Finally, tools must be validated in samples of WYC prior to wide administration. Only once an accurate picture is gathered of the habitual health-enhancing physical activity of WYC, will it be possible to determine whether WYC are in fact a population at risk or whether they are simply considered at risk because their patterns of physical activity differ from what is known of the general population.

### **Demographic variations in discrepancies between objective and subjective measures of physical activity**

#### **Preface**

Outcomes of the systematic review in Chapter 3 draw attention to the dominance of self-report tools in studies of physical activity in women with young children. Review of construct and criterion validity highlighted that self-report tools may not accurately or reliably capture the predominant forms of physical activity in this population. It is possible that parents are more active than previous evidence would suggest. The purpose of this chapter is to investigate the utility of self-report methodologies for physical activity quantification in samples of men and women with young children. This study examines the association between MVPA derived from the International Physical Activity Questionnaire long-form version (IPAQ-LF) and concurrent accelerometer-derived MVPA in a large heterogeneous sample. Limitations of self-reports are widely acknowledged, however previous studies have not considered whether their validity varies between different demographics, such as men and women, and parents and non-parents. The findings from this study contribute to wider understanding of behavioural measurement methodology in both adult and parent populations, and informed the choice of measurement tool for application in ensuing studies in this thesis. This chapter has been published by the peer-reviewed journal, Open Journal of Preventive Medicine.

## Abstract

Demographic effects (sex and parenthood status) on the level of association between self-reported and accelerometer assessed physical activity were examined among a large diverse sample of adults. Participants ( $n = 1,249$ , aged 20–65 years) wore accelerometers (Actical) for 7 days and completed an interviewer-administered physical activity recall questionnaire (IPAQ-LF) for the same period. Mean daily minutes of moderate physical activity (MPA) and MVPA were used in analyses. Linearity between methods was explored by regressing mean minutes of activity and Pearson's correlations were performed. A weak association between IPAQ-LF and Actical minutes of MPA and MVPA per day was shown for the whole sample ( $r_s = .22-.26$ ). The magnitude of association varied between males ( $r_s = .27-.37$ ) and females ( $r_s = .12-.17$ ), although no obvious variations in associations were evident for parenting status. The IPAQ-LF produced substantially greater variations in estimates of physical activity than that recorded by the Actical accelerometer and large discrepancies between methods were observed at an individual level. Self-report tools provide a poor proxy of overall human movement, particularly among females. Inferences made at an individual level from self-reported data, such as intervention efficacy or health outcomes, may have substantial error.

## Introduction

Physical activity is an essential behavioural element in maintaining good health, preventing disease, and prolonging longevity.<sup>5</sup> The epidemiology of physical activity considers the association physical activity and inactivity have with chronic diseases, and the mechanisms to prevent and control these diseases. Accurate monitoring of physical activity engagement in free-living populations is central to correctly determining the direction and magnitude of these associations and mechanisms. Conventionally emphasis has been placed on measuring moderate and vigorous physical activities performed in leisure domains, although more recently non-leisure domains (e.g., occupational, transport, household) have featured. In response to growing evidence for the poor health outcomes associated with sedentary behaviours<sup>32,71</sup> and the positive health effects of low-level activity,<sup>220,221</sup> a call has been made to incorporate these behaviours in measures of physical activity so that they may be tracked and health outcomes determined.<sup>72,75</sup>

In the absence of an agreed-upon criterion for quantifying physical activity many types of measures are applied.<sup>237</sup> Self-report tools (e.g., questionnaires, diaries) are the most widely-used measure of physical activity at a population level. Inherently, these tools rely on participants' ability to accurately recall, quantify, and categorize their physical activity behaviours according to the framework of the self-report tool. Conversely, motion sensors (e.g., accelerometers, some pedometers) can be used to provide an objective assessment of the accumulation of activity movement (commonly lower body movements) throughout a period of time. Accelerometers (e.g., Actigraph, Actical, Caltrac) use piezoelectricity to register acceleration, recording detailed temporal data across the spectrum of activity intensity, including sedentary behaviours and low-level activity.

Many epidemiological studies using self-report measures have shown women to be less active than men.<sup>238</sup> Moreover, some sub-groups of women, such as women with young children (WYC), are thought to be even less active.<sup>18</sup> In part, this may be due differences in the way physical activity is performed and thus measured. Firstly, planned activities and those performed at vigorous-intensity are most memorable and are therefore more likely to be accurately recalled. Whereas, WYC are known to spend longer durations in total work (paid and unpaid) each day than men with young children (MYC) and women without young children,

potentially leaving less time for planned leisure.<sup>94</sup> This may also be the case for MYC compared to those without children (MNYC). Additionally, activities of WYC are often sporadic and performed simultaneously with other tasks, for example, carrying a child whilst vacuuming. These types of activities are regularly interrupted with needs of young children that need tending, and difficult to categorize and quantify through self-report.<sup>154</sup> Yet, accelerometers have the ability to record movement regardless of duration, intensity or purpose. It is possible therefore, that systematic differences in the validity of self-report tools may be present across major demographics.

A variety of self-report tools exist, and many studies have examined the validity of self-report tools using accelerometry as the criterion, or objective, measure of physical activity. Previously, discrepancies between objective and subjective measures of physical activity have been shown within adult populations;<sup>58,223</sup> however it is unknown whether these discrepancies vary by certain demographic variables. If this were the case, it would have significant bearing on the selection of measurement tools dependent upon the population being studied. The IPAQ was developed following an international collaboration to develop a standardized self-report measure of physical activity suitable for population-wide assessments of physical activity.<sup>239</sup> The IPAQ-LF requires recall of physical activity engagement at moderate and vigorous intensities for occupational, transport, household, and leisure domains for a 7 day period (either usual or previous).

This study examines the association between activity derived from the IPAQ-LF and concurrent accelerometer derived activity, and, the potential methodological impact on mis-measurement imposed by differences in sex and adults' parenting status. The aims of this study were therefore to: 1) examine the level of association between self-reported and accelerometer assessed physical activity engagement in a large sample of adults, and 2) determine differences in the level of association between measures among men and women with and without young children (aged 0–4 years).

## Methods

Participants were part of the URBAN Study, a multi-centred, stratified, cross-sectional study of associations between physical activity, health, and the built environment in adults and children

residing in New Zealand.<sup>240</sup> Objective and self-reported physical activity engagement, neighbourhood perceptions, demographics, and body size measures were collected, along with built environment variables. The study contributes to a larger, international collaborative project where similar procedures are utilized across eight countries ([www.ipenproject.org](http://www.ipenproject.org)).

## **Participants**

Adults aged 20 to 65 years were recruited randomly from 48 neighbourhoods (stratified by high–low walkability, high–low Māori population) across four New Zealand cities during 2008–2010. Trained interviews followed pre-determined walk paths for each neighbourhood and approached every nth house, according to the neighbourhood household sampling rate. One adult from each household was invited to participate. Further details of the neighbourhood selection, recruitment methods, and sample power calculations have been described elsewhere.<sup>240</sup>

## **Data collection**

Trained interviewers gained written informed consent and delivered accelerometers and travel/compliance logs during the first home visit. Eight days later, the interviewer visited the home a second time to collect the accelerometer and travel/compliance log, measure participants' height, weight, waist, and hip circumferences, and to administer the study questionnaire.

## **Measures**

A range of measures were utilized in the URBAN study. Those relevant to the current study are outlined below:

### ***Objectively assessed physical activity***

Hip-mounted Actical accelerometers (Mini-Mitter, Sunriver, OR) were used to objectively measure participants' physical activity. The units have been shown to be a reliable and valid measure of physical activity in adult populations.<sup>241,242</sup> Accelerometers were prepared to record physical activity and step counts in 30-second epochs. Participants were instructed to wear the unit for all waking hours (excluding water-based activities) for seven consecutive days. Participants self-completed a compliance log of wear-time and activities the participant engaged



in whilst not wearing units, for the duration of accelerometer data collection period. The information derived from the log was checked and matched against accelerometer data.

### ***Self-reported physical activity***

The IPAQ-LF was administered via interview at the second home visit to capture adults' self-reported physical activity for the previous seven days (the period when the accelerometer was worn). The IPAQ-LF assesses frequency (days), duration (minutes), and intensity (walking, moderate, vigorous) of physical activity engagement across four domains: occupation, transportation, household, and leisure. Moderate physical activity was defined as "those activities that take moderate physical effort and make you breathe somewhat harder than usual"; vigorous physical activity as "those activities that take hard physical effort and make you breathe much harder than normal".<sup>243</sup> Evidence for the reliability and validity of this tool has been provided for 744 adults across 12 countries.<sup>239</sup>

### ***Demographics***

Participants completed a demographic survey that included: gender, ethnicity, marital status, household income, academic qualifications, occupation, dwelling type, and the number and ages of children living in the dwelling.

## **Data treatment**

### ***Self-reported physical activity***

According to the IPAQ scoring protocol ([www.ipaq.ki.se/](http://www.ipaq.ki.se/)), minutes of physical activity engagement from the IPAQ-LF were summed across activity domains for each level of intensity (walking, moderate, and vigorous). Mean daily minutes of moderate (sum of walking and moderate, MPA), vigorous (VPA), and sum of MPA and VPA (MVPA) activity engagement were calculated to minimize the effect of missing days of accelerometer data.

### ***Objectively assessed physical activity***

Accelerometer data were downloaded using Actical® version 2.04 (Mini-Mitter Co., Inc., Bend, OR, USA). Thresholds for MPA and VPA were generated by the Actical software and were based on MET-value based cut points. Data were prepared for analysis within the Statistical

Analysis System (version 9.1, SAS Institute Inc., Cary, NC, USA) and Microsoft Excel. Bouts of 60 or more consecutive minutes of zero counts were considered non-wear-time and extracted prior to analysis.<sup>244</sup> Wear-time criteria for inclusion were defined as having five or more days of 10 or more hours of wear-time per day. Mean daily minutes of MPA, VPA, and MVPA activity were used in all analyses to ensure comparability across the sample. Mean values for individuals were calculated using the number of days of accelerometer wear that met wear-time criteria.

## **Statistical analyses**

All analyses were undertaken using SPSS (version 18) and statistical significance was set at  $\alpha = .05$ . Shapiro-Wilk's test of normality was conducted for both physical activity measures, and non-normal distributions were log transformed to achieve normality. Means and standard deviations were used to describe both methods of measurement for the whole sample and each demographic (WYC, women with young children [children aged 0–4 years]; MYC, men with young children; WNYC, women with no young children; MNYC, men with no young children).

Commonly, correlation coefficients are used as a single score of validity between measures however it is appropriate to explore associations with a broader view. Firstly, a test of the differences between measurement means allows quantitative assessment of whether methods are significantly different from each other. Secondly, a scatter plot of the two measures with the line of identity provides visual assessment of linearity and systematic or random bias in the relationship between measures. The correlation coefficient can then be calculated as a summary of the overall scatter between measures, indicating the strength of the linear relationship.<sup>245</sup> Therefore, paired t tests were used to compare means between methods, and linearity was explored by regressing mean minutes of activity at each intensity derived using the IPAQ-LF against mean minutes of Actical. Evaluation of linear relationships between Actical and IPAQ-LF using Pearson's correlation were performed. Results are presented for the whole sample and comparisons made between demographic groups (WYC, MYC, WNYC, MNYC).

## Results

### Participants

A total of 2,013 adults aged 20–65 years participated in the URBAN study between April 2008 and September 2010. Participants with missing demographic ( $n = 4$ ) or IPAQ-LF ( $n = 5$ ) data were excluded, as were participants who did not meet criteria for accelerometer wear-time ( $n = 731$ ). Outliers in IPAQ-LF data were calculated using interquartile range (IQR) computation, where any value more than 3 IQR above the third quartile were considered a problematic outlier ( $n = 24$ ). Therefore data from 1,249 participants were included in these analyses (Table 7).

### Moderate physical activity

Descriptive statistics, presented in Table 7, indicate that the IPAQ-LF reported significantly higher means of MPA engagement than the Actical ( $t = 2.10$ ,  $p < .05$ ). Additionally, standard deviations of the means were substantially greater for the IPAQ-LF indicating greater variance in self-reported activity levels. The scatter plot demonstrated a weak relationship between measures, as can be observed in Figure 3 whilst the regression line passes the line of identity ( $\log y = \log x$ ) near the means for both measures, the scatter indicates significant random bias. Further, evaluation of the linear relationship between methods indicated a weak association ( $r = .22$ ,  $p < .001$ ). All demographic groups reported higher mean estimates of MPA by IPAQ-LF than measured by Actical, however these differences were only significant in MNYC ( $t = 2.68$ ,  $p < .05$ ). Weak associations between methods were found for both WYC and WNYC ( $r = .12$ ,  $p = .16$  and  $r = .13$ ,  $p < .01$  respectively), while for MYC and MNYC a linear (albeit weak-moderate) relationship was found between measures ( $r = .27$ ,  $p < .05$  and  $r = .33$ ,  $p < .001$ , respectively).

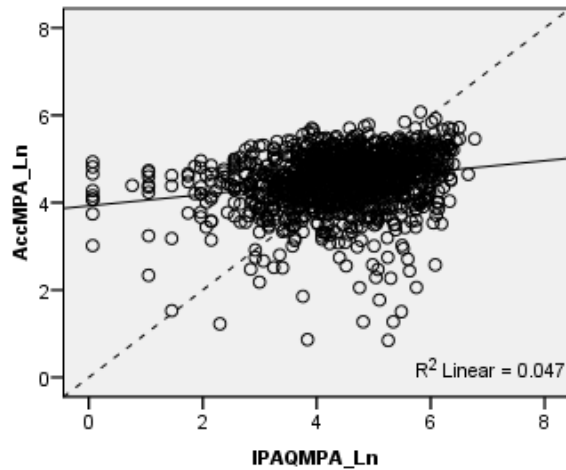
### Moderate-to-vigorous physical activity

Actical derived MVPA increased marginally from MPA whereas IPAQ-LF MVPA values increased disproportionately indicating much greater vigorous activity via self-report compared with objective measurement (Table 7). As was observed with MPA, paired t-test results revealed significant differences between method means ( $t = -3.39$ ,  $p < .001$ ) and weak association between methods ( $r = .26$ ,  $p < .001$ ). Scatter plots continued to show significant random bias in self-report (Figure 4).

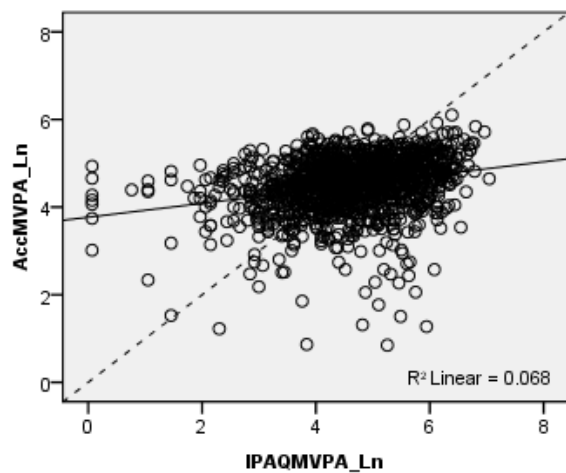
**Table 7.** Participant characteristics and descriptive statistics of IPAQ-LF and Actical measures

	Total sample <i>N</i> = 1,249	WYC <i>n</i> = 128	MYC <i>n</i> = 84	WNYC <i>n</i> = 588	MNYC <i>n</i> = 449
Age					
18 – 25	121	10	8	50	53
26 – 35	254	52	32	93	77
36 – 45	353	55	34	161	103
46 – 55	301	6	9	175	111
56 – 65	213	4	1	106	102
Missing	7	1	0	3	3
Height cm*	169 ± 10	165 ± 7	178 ± 6	164 ± 8	177 ± 7
Weight kg*	77 ± 17	72 ± 18	86 ± 14	70 ± 16	84 ± 16
BMI kg/m <sup>2</sup> *	27 ± 8	27 ± 6	27 ± 4	27 ± 11	27 ± 5
Moderate physical activity					
Actical (min·day-1)*	107 ± 58	105 ± 57	114 ± 57	101 ± 54	112 ± 62
IPAQ-LF (min·day-1)*	135 ± 128	132 ± 111	181 ± 185	125 ± 138	140 ± 138
Correlation	<i>r</i> = .22, <i>p</i> < .001	<i>r</i> = .12, <i>p</i> = .16	<i>r</i> = .27, <i>p</i> < .05	<i>r</i> = .13, <i>p</i> < .05	<i>r</i> = .33, <i>p</i> < .001
T-test	<i>t</i> = 2.10, <i>p</i> < .05	<i>t</i> = -0.21, <i>p</i> = .838	<i>t</i> = -0.11, <i>p</i> = .912	<i>t</i> = 0.90, <i>p</i> = .372	<i>t</i> = 2.68, <i>p</i> < .05
Moderate-vigorous physical activity					
Actical (min·day-1)*	107 ± 58	105 ± 57	115 ± 57	101 ± 54	113 ± 63
IPAQ-LF (min·day-1)*	161 ± 158	140 ± 116	227 ± 234	141 ± 123	180 ± 184
Correlation	<i>r</i> = .26, <i>p</i> < .001	<i>r</i> = .16, <i>p</i> = .07	<i>r</i> = .34, <i>p</i> < .005	<i>r</i> = .17, <i>p</i> < .001	<i>r</i> = .37, <i>p</i> < .001
T-test	<i>t</i> = -3.39, <i>p</i> < .001	<i>t</i> = -1.14, <i>p</i> = .255	<i>t</i> = -2.53, <i>p</i> < .05	<i>t</i> = -2.06, <i>p</i> < .05	<i>t</i> = -1.60, <i>p</i> = .11

\*Values are presented as Mean ± Standard Deviation.



**Figure 3.** Association between self-report and accelerometer derived MPA for the whole sample. Note. Dashed line represents line of identity; solid line represents linear regression line. Refer to Appendix D for demographic-specific figures.



**Figure 4.** Association between self-report and accelerometer derived MVPA for the whole sample. Note. Dashed line represents line of identity; solid line represents linear regression line. Refer to Appendix D for demographic-specific figures.

All demographic groups self-reported more MVPA than recorded by accelerometer, and both male groups self-reported substantially greater VPA than either female group. Significant differences were observed between methods for MVPA means for MYC, and WNYC, but not for WYC or MNYC. Methods were moderately correlated for MVPA for both male groups ( $r = .337$ ,  $p = .002$  and  $r = .366$ ,  $p < .001$ , respectively) yet both female groups showed similarly weak associations ( $r = .161$ ,  $p = .069$  and  $r = .167$ ,  $p < .001$ , respectively).

## Discussion

This study investigated the demographic effects of sex and parenthood status on associations between a self-report tool (IPAQ-LF) and objective method (Actical accelerometry) for describing MPA and MVPA in adults. A weak linear relationship between IPAQ-LF and Actical minutes of MPA and MVPA per day was shown and the magnitude of association varied between men and women; no obvious variations in associations were evident for parenting status.

It is evident from the regression plots that the IPAQ-LF produces greater variation in estimates of physical activity variables than recorded by the Actical accelerometer, which is reflected by the weak associations found between measures across all demographic groups. Importantly, at a population level the method means were similar however substantial discrepancies between measures occurred at an individual level. This indicates that inferences made at an individual level, such as intervention efficacy or health outcomes, may have substantial error; the utility of self-report tools for such a purpose is therefore questionable for all demographic groups, however this may be more so among women. Previous IPAQ-LF validation studies have reported moderate associations with accelerometry ( $r = .30-.33$ )<sup>239,246</sup> and doubly labelled water ( $r = .31$ )<sup>247</sup> for describing MVPA in adults. None of these studies reported demographic-specific associations, although similar associations were reported across 12 countries, including developing countries.<sup>239</sup> In the validation study of a self-report tool developed for use among WYC incorporating a variety of domains, comparably weak associations of self-reported MVPA with accelerometer-derived MVPA were reported ( $r_s = .13$ ).<sup>146</sup> The same study reported improved associations when considering MVPA from planned and transport domains of activity only ( $r_s = .28$ ).

Moderate associations between self-reported and accelerometer-derived physical activity are typical.<sup>223,233</sup> Because of their widespread availability, low cost, and ease of use, self-report tools continue to be employed despite their well-documented shortcomings.<sup>239</sup> In particular, self-report tools are cognitively challenging; they require participants to recall, estimate, and classify physical activity engagement, usually over a 7 day period. A study that probed respondents for clarification of self-reported responses found 74% over-reported, 10% under-reported, and 16% reported total activity accurately.<sup>248</sup> Social desirability bias may also lead to over-inflated

estimates of physical activity behaviour. Further, self-report tools are biased to certain patterns of activity; planned activities and those of vigorous-intensity are more accurately and reliably recalled than low-level intermittent behaviours.<sup>239,248</sup> The latter methodological flaw potentially misses vast quantities of health-enhancing activity, especially in those who are unable or lack opportunity to participate in vigorous-intensity activity. Efforts have been made to rectify this somewhat by attempting to capture time spent in occupation and domestic physical activities. Arguably however, physical activity performed in these domains is often low-level and intermittent, therefore difficult to recall accurately. A common feature of self-report tools is also to exclude activity bouts of < 10 min. Whilst this may improve the reliability in recalling behaviour it systematically excludes activities regularly promoted as health enhancing, such as using stairs instead of the elevator, parking further away and walking the extra distance, and many domestic and yard activities of moderate-intensity. Algorithms to extract minimum bouts of activity recorded by accelerometers (e.g.,  $\geq 10$  min, allowing 1–2 min interruption within each bout) have been promoted and utilized in some studies in order to provide comparability with many self-report tools.<sup>83,138,249</sup> Whilst this method may produce greater convergence between measures, this may simply be case of biasing the objective measure to systematically miss more actual activity. Such methods were not used in this study because of its inherent limitations. Firstly, activity which most health professionals would regard as “health-related” is often not conducted in one continuous bout, even after allowing for a 1–2 min interruption, and may fluctuate between light-intensity and vigorous intensity, as is common place in many sports and recreational activities. Further, this approach may exclude significant contributions that short bouts of activity make to overall daily physical activity.

It is likely that patterns of activity may contribute to the sex effects observed in this study. Particularly, women (both with and without young children) may be more likely to perform low-level intermittent activity than engage in planned bouts of vigorous-intensity activity, potentially producing greater variability in reporting. It appears that sex has a greater effect on self-report accuracy than parent status; this may be due to the presence of confounding factors such as parental employment, presence of older children, socioeconomic status, and marital status. The IPAQ battery of questionnaires were developed in an attempt to provide a standardized self-report tool suitable for population estimates of the prevalence of physical activity so that comparisons between countries may be made.<sup>239</sup> Whilst there is some merit in this purpose at a

population level, the application of self-report tools to determine health outcomes of physical activity behaviour is inappropriate. The present study has concurred with previous research demonstrating a weak-to-moderate association between self-reported and accelerometer derived behaviour.<sup>58,223</sup> Importantly however, this research further shows that the ability of self-report tools to capture overall activity is particularly weak among women, probably due to lower levels of planned moderate- to vigorous-intensity activity. With greater emphasis now being placed on measuring physical activity across the spectrum it is important that measurement tools are capable of doing so accurately.

The strengths of this study include its large heterogeneous sample with a spread of demographics providing adequate variations in physical activity for exploring associations across a full range of activity levels. It appears that the sample in this study were highly active, although this is an acknowledged outcome of the IPAQ-LF given the number of domains considered.<sup>239</sup> A limitation of the study is that it was not methodologically designed for measurement tool validation, reflected by the high proportion of participants that were excluded due to inadequate accelerometer wear-time. This study demonstrates substantial discrepancies between self-report tools (specifically the IPAQ-LF) and accelerometer derived physical activity. Findings indicate that self-report tools provide a poor proxy of human movement, especially among women. Careful consideration must be given to the patterns of activity in the intended study population and the purpose of measurement.



## Chapter 5

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### **Physical activity at sedentary, light, and moderate-to-vigorous intensities:**

#### **A study of adults with and without young children**

#### **Preface**

The outcomes of Chapters 3 and 4 indicate substantial limitations to current knowledge of physical activity among adults with young children. Firstly, knowledge is limited to MVPA in predominantly leisure domains. Secondly, Chapter 4 identifies inaccuracies in self-report estimates of physical activity, particularly among women. It is evident that much is yet to be understood of the whole picture of physical activity behaviours among parents. This chapter is the first of three that describe in detail the amounts and patterns of physical activity accumulated by adults with young children, and how this might compare against adults without young children. Accelerometers have the utility of capturing ambulatory movement—the predominant source of physical activity—regardless of its duration, intensity, or context. As noted in Chapter 3, at the commencement of this thesis no published studies had reported accelerometer-derived physical activity estimates of adults with young children compared with adults without children. Since then two studies have been published, however there remain no reports of accelerometer-derived sedentary time or light-intensity activity. Therefore, the purpose of this study is to utilise accelerometers to investigate the overall amounts of physical activity across the full spectrum of intensity among adults with and without young children. The findings from this study will provide a broader picture of how adults with young children engage in physical activity behaviours, in terms of the intensity of movement.

## Abstract

**Background:** Opportunities for sustained and purposeful physical activity are limited for parents with young children. Given the substantial amount of time spent in childcare and household related tasks, it is likely that parents accumulate a significant proportion of their daily physical activity in light-intensity activity. However there is little understanding of the distribution of time spent in sedentary, light, and moderate-to-vigorous intensities. The purpose of this study was to investigate physical activity across the full spectrum of intensity among adults with and without young children in the household.

**Methods:** Data were from a multi-centre, stratified, cross-sectional study of physical activity in adults (aged 20–65 years;  $N = 2,013$ ) residing in New Zealand. Physical activity was measured using accelerometry. Analyses were performed for hourly observations of step counts and proportion of time at sedentary, light, and moderate-to-vigorous intensities using mixed models to determine the associations of young children in the household on physical activity. All models were adjusted for city, daily temperature, and daily rainfall, and took into account repeated measurement factors.

**Results:** Trivial differences were observed for overall mean steps per day between adults with young children and those with no children (8,700–11,000 and 9,400–11,000 steps per day, respectively), however differences in the distribution of time across intensities were observed. Overall, having a young child in the household was associated with proportionately less time in MVPA, more time in light-intensity activity, and less sedentary time. The magnitudes of differences between those with and without young children in the household were generally larger for women than men, and on non-work days compared to work days.

**Conclusions:** Adults with young children in the household accumulate more physical activity than has previously been recognised. Health promotion messages for parents should acknowledge the high levels of light-intensity activity occurring through daily living and its contribution to reducing sedentary time and increasing overall physical activity.

## Background

Becoming a parent has been identified as a key life change event that affects participation in physical activity.<sup>124,250,251</sup> Life change events are “those occurrences, including social, psychological, and environmental, which require an adjustment or effect a change in an individual’s pattern of living”.<sup>96</sup> Having a child is a critical juncture in life that effects a change in adults’ patterns of living in a substantial and long lasting way and thus may have a profound impact on their physical activity. The disruption to an adult’s daily routine on the birth of a child<sup>251</sup> requires the re-establishment of new parameters, roles, responsibilities, and routine. It is under these conditions that parents find they must renegotiate traditional constraints (e.g., time, cost, social support, resources), along with the more pressing unique parental constraints such as lack of energy,<sup>18,19,128,167,179,189</sup> responsibilities to children and others,<sup>17-19,169,188</sup> and structural constraints (e.g., restricted time, lack of childcare, child routines).<sup>19,128,189</sup> Together these parenting parameters limit opportunities for sustained and purposeful physical activity. What is more, an ‘ethic of care’ arises whereby parents place the needs of others above their own<sup>16,17,19,190</sup> and as such new meanings of physical activity may need to be developed within their new social identity as parent.<sup>20,169</sup>

A systematic review of parental physical activity concluded that parents were less active than their childless counterparts.<sup>18</sup> Two large prospective studies included in this review showed that women who became mothers were more likely to decrease their activity or remain inactive than those who remained childless.<sup>122,124</sup> To date, studies have focussed predominantly on MVPA and relied on self-reports of physical activity behaviour,<sup>252</sup> and very few studies have examined the relationship between parenthood and physical activity among men. Recently however, two studies incorporated accelerometer technology to objectively assess parental physical activity among men and women.<sup>15,35</sup> These large representative cross-sectional studies explored differences in accelerometer-measured MVPA among adults with and without children (< 18 years), and the effects of having a young child on parental activity. Findings from the Canadian Health Measures Survey<sup>35</sup> showed that having a child < 6 years was negatively associated with adults’ MVPA (bouts ≥ 10 min), and this association was stronger in women. In contrast, the U.S. Neighborhood Quality of Life Study<sup>15</sup> found no differences in MVPA physical activity between adults with children < 5 years, and those with no children or older children. One reason

for the inconsistencies in results between these two studies may be the application of MVPA bout criteria to one study<sup>35</sup> and not the other.

Although it is clear from existing studies that parenthood affects physical activity in some way, there is still little understanding of whether the distribution of time spent in sedentary, light, and moderate-to-vigorous intensity activity is different among parents compared to the adult population. Some studies have suggested that the mode of physical activity changes, with parents engaging in less exercise but more household and daily living activities.<sup>15,146,251</sup> Given the substantial amount of time spent in childcare and household related tasks, compared with nonparents,<sup>94,102</sup> it is likely that parents accumulate a significant proportion of their daily physical activity in light-intensity activity and as such, potentially less sedentary time than nonparents. This is of particular interest in view of recent understanding that sedentary time and MVPA are distinct behaviours with independent associations with health.<sup>74</sup> The purpose of this study, therefore, was to investigate how the presence of young children (< 5 years) affects overall amounts of physical activity and the distribution of time spent in sedentary, light, and moderate-to-vigorous intensities. Accounting for physical activity across the full spectrum of intensity offers an original analysis of the impact of children on adults' physical activity. In addition, the differences between adults with young children, older children, and no children were examined.

## **Methods**

Data were drawn from the URBAN study, a multi-centre, stratified, cross-sectional study of associations between physical activity, health and the built environment in adults and children residing in New Zealand.<sup>240</sup> Ethical approval to conduct the study was provided by the host institutions' ethics committees (AUTC: 07/126, MUHECN: 07/045).

### **Participants and recruitment**

Participants were recruited randomly from 48 selected neighbourhoods (stratified by high–low walkability, high–low Māori population) across four New Zealand cities. Data were collected between April 2008 and September 2010. Full details of neighbourhood selection, participant recruitment, data collection, and sample size calculations are described elsewhere.<sup>240</sup> In brief, a door-to-door recruitment strategy was utilised, where every  $n^{\text{th}}$  household within each neighbourhood was sampled. One adult aged 20–65 years from each household was randomly

selected (using next birthday enumeration) and invited to participate. Eligibility criteria were within the age range, English speaking, able to walk without aids (for physical activity measurement), and resident in the household at least three months prior to, and for the week during, the measurement period.

## **Measures**

On the recruitment visit, trained interviewers gained written informed consent and delivered accelerometers and travel logs. Eight days later, the interviewer returned to the home to collect the accelerometer and travel log, and measure participants' height, weight, and waist and hip circumferences. Participants also completed a 40 min computer-assisted personal interview with a trained interviewer that assessed individual and household demographics, neighbourhood perceptions and preferences, physical activities, and sedentary behaviours. Measures specific to the current study only are detailed below.

*Physical activity:* Objective measures of participants' physical activity were recorded using hip-mounted Actical accelerometers (Mini-Mitter, Sunriver, OR). The units have been shown to be a reliable and valid measure of physical activity in adult populations.<sup>241,242</sup> Participants were instructed to wear the accelerometer units during waking hours for 7 consecutive days. The units were set to record physical activity in 1 min epochs.

*Children in household:* Participants reported the ages of all children aged < 18 years residing in the dwelling during the 7 day period prior to survey completion.

*Demographic information:* Participants reported their sex, date of birth, ethnicity, combined household income, employment status, and marital status. Age was calculated from the date of birth as at the date of survey collection.

## **Data treatment**

Actical export files (version 02.10) of raw accelerometer and step-count data for each participant were read into and plotted within the Statistical Analysis System (version 9.2; SAS Institute, Cary, NC) for checking. Device event markers and information derived from the compliance log were checked and matched against the accelerometer plots to determine valid wear time. Zero

counts for > 59 contiguous min were categorised as non-wear time and set to missing.<sup>244</sup> It has been previously testified that application of stringent wear-time criteria may introduce bias to the study, whereby wear compliance may be correlated with physical activity levels.<sup>37,194</sup> As such any day that had a minimum of 6 h wear-time was considered a valid day. Count thresholds used to categorise sedentary and physical activity were as follows: < 100 cpm defined sedentary time,<sup>253</sup> 100-999 cpm defined light-intensity activity and  $\geq 1,000$  cpm defined MVPA. The MVPA threshold was determined by best-fit of data simulations (unpublished data) using the Crouter 2R equations.<sup>254</sup> Accelerometer data were reduced to hourly summaries (0600 – 2259 hours; 17 periods); each hourly observation was then weighted by the number of recorded minutes. Hourly observations of accelerometer data were expressed as mean step counts per hour accumulated in light steps (< 1,000 cpm), moderate steps ( $\geq 1,000$  cpm), and total steps, and also as mean proportion of the number of minutes of recording per period (up to 60 min) spent in sedentary time, light-intensity activity, and MVPA.

For the analysis of the effect of children in the household, participants were partitioned into three groups: those with any child aged < 5 years (hereafter young child), those with any child aged 5–12 years (hereafter older child), and those without any child aged < 13 years (hereafter no child). Work days included Monday to Friday and non-work days were specified as weekend days and any public holiday during participants' measurement period. Individual adult income was derived as the average of the combined household income by the number of adults living in the household. Age at the date of survey completion was categorised into low (20–39 years), mid (40–52 years), and high (52–70 years) tertiles based on even distribution across the whole study sample. New Zealand age-specific fertility rates in 2010 were highest among those aged 30–34 years, followed by 25–29 years, and 20–24 years, with a rapid decline from 40 years.<sup>105</sup> As such, in the interest of brevity this paper presents results for the low age tertile only (See Appendix E for mid and high age tertiles tables).

## **Statistical analysis**

Separate analyses were performed for hourly observations of light steps, moderate steps, and all steps using the mixed model (Proc Mixed) in SAS. Raw step counts were used in all step analyses, as log transformed counts showed greater non-uniformity of the residuals than non-transformed counts. The fixed effects in the mixed model included main effects to adjust for city

(four levels), maximum daily temperature (numeric), and daily rainfall (two levels, presence or lack of rain). Presence of children in household (three levels) was included as an interaction with hour of the day (17 levels) to generate daily activity profiles of the three children-in-household groups. Random effects were included in the model to account for repeated measurement from hour to hour and from day to day; the effects were the identity of the participants, the interactions of their identity with identity of the hour and identity of the day, and the residual. Fixed and random effects for the analysis of proportions were the same as those for the analysis of step counts, but the generalized mixed model (Proc Glimmix) was used. The logit link function and the binomial distribution were invoked to effectively specify logistic regression. The residual was specified as over dispersed binomial to account for the clustering of minutes via bouts of activity, with a different over dispersion factor for each of the three subgroups of children in the household.

Each of the above analyses was performed separately for males and females in each of the age tertiles on work days and non-work days. Mean levels of activity and effects on activity are shown as mean steps per day (the hourly mean multiplied by 17 periods) and as proportions in an average hour. Differences in means for work days with non-work days were examined within sub-groups by running additional analyses with type of day replacing presence of children as a main effect in the model.

An inference about the true value of a given effect (a difference in means) was based on its uncertainty in relation to the smallest important difference, which was determined by standardisation as 0.20 of the pure between-subject standard deviation within the two compared subgroups;<sup>40</sup> this standard deviation was derived from the random effect for the identity of the participants in the mixed model. Inferences were non-clinical: an effect was deemed unclear if the 90% confidence interval included the smallest important positive and negative differences; the effect was otherwise deemed clear. Effects that were clear with the more conservative 99% confidence interval are also indicated. The magnitude of a given clear effect was determined from its observed standardised value (the difference in means divided by the between-subject standard deviation) using the following scale: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate;  $\geq 1.20$ , large.<sup>40</sup>

## Results

### Participants

A total of 2,013 adults, mean age 46 years (*SD* 12), participated in the URBAN study between April 2008 and September 2010 (response rate 44%). For practicality, this article presents results for the low age tertile only (see Appendix E for supplementary tables on mid and high age tertiles). Figure 5 demonstrates the flow of participant recruitment and inclusion.

Demographic characteristics of the adults included in these analyses are shown in Table 8. On average, adults in the low age tertile provided 6 days (*SD* 2, range 1–9 days) of valid data and daily wear time for each participant was 13 h (*SD* 1.8, range 6–16 h).

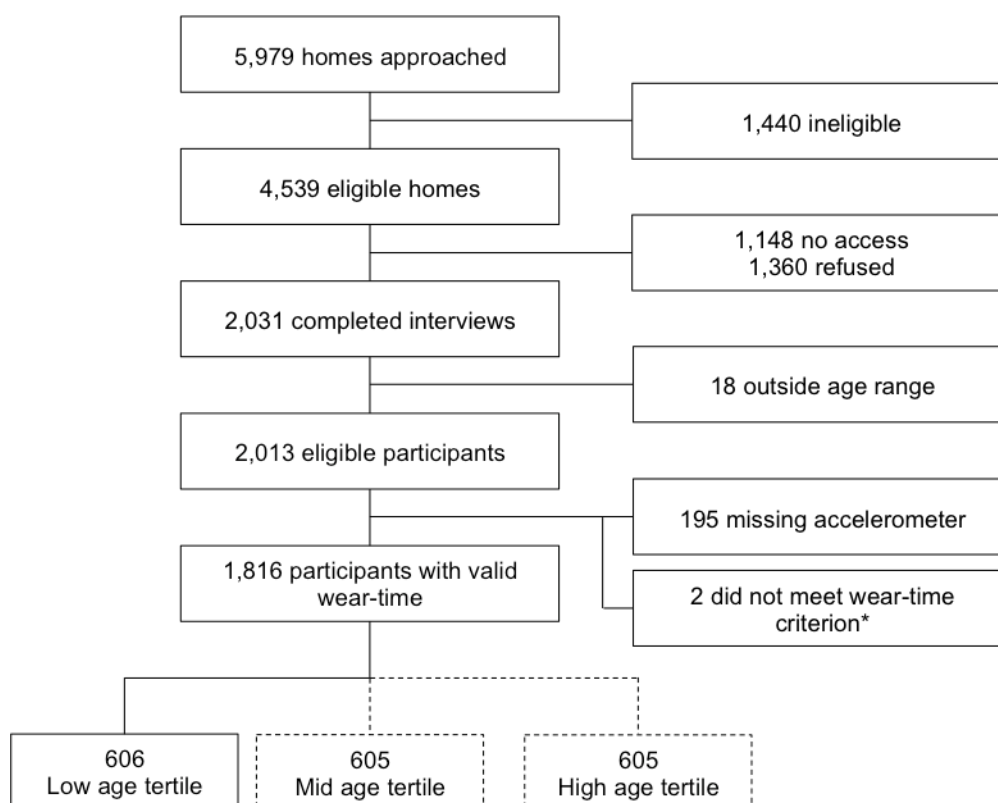
### Overall physical activity

Physical activity accumulated from all sources and across all intensities is summarised by total mean step counts per day (Table 9). On work days, trivial differences were observed between women with and without young children; however there was a small difference on non-work days. For men, differences in total step counts per day were unclear at the 90% level.

### Moderate-to-vigorous physical activity

Men and women with young children recorded fewer minutes per day above the moderate-intensity threshold than those without young children (Table 8). The proportion of time spent in MVPA for all groups are shown in Table 10. On work days, women with young children spent a smaller proportion of time in MVPA compared with women with older children (difference ~5 min per day) and no children (difference ~9 min per day), and accumulated fewer steps per day above the moderate-intensity threshold. On non-work days, the magnitude of difference between women with and without young children was greater, with a large effect size observed. Similar differences were seen among men, albeit smaller in magnitude; men with young children spent less time in MVPA (difference ~3–6 min per day) and accumulated fewer steps per day than those without children, on both work days and non-work days.





**Figure 5.** Participant recruitment flow chart.\*Wear-time criterion: > 1 day and ≥ 6 h per day

**Table 8.** Characteristics of the participants in the low age tertile sorted by men and women with and without children at home.

	Men			Women		
	Young child (n = 73)	Older child (n = 22)	No child (n = 177)	Young child (n = 99)	Older child (n = 46)	No child (n = 189)
Age (y)	34 ± 4	33 ± 6	31 ± 5	33 ± 5	34 ± 5	31 ± 5
Ethnicity (%)						
Maori/Pacific	33	41	18	28	37	11
Asian	10	18	10	14	15	13
European	58	41	72	58	48	76
Bachelor degree (%)	26	14	37	44	14	54
Income per adult (\$000)	34 ± 17	33 ± 16	30 ± 20	34 ± 20	30 ± 18	31 ± 22
Work Status (%)						
Paid work	86	68	79	48	63	78
No paid work	14	32	21	52	37	22
Marital Status (%)						
Single	12	41	55	13	46	48
Married or with partner	85	55	43	82	50	47
Previously married	3	5	2	5	4	5
Number of children (%)						
1 child	55	59	0	36	57	0
> 1 child	45	41	0	64	43	0
Physical activity (min/day†)						
Sedentary	740 ± 100	740 ± 98	750 ± 96	720 ± 100	770 ± 94	770 ± 95
Light-intensity activity	250 ± 88	240 ± 88	220 ± 83	270 ± 96	210 ± 83	210 ± 82
MVPA	17 ± 13	15 ± 11	23 ± 17	13 ± 10	18 ± 13	22 ± 17

Measures of centrality and dispersion are mean ± SD. † work days only. See Appendix E for subject characteristics of the mid and high age tertiles.

**Table 9.** Differences in light, moderate, and total steps per day on work days and non-work days among men and women with and without children at home.

	Men				Women			
	Young child (n = 73)	Older child (n = 22)	No child (n = 177)	Btwn-subject SD	Young child (n = 99)	Older child (n = 46)	No child (n = 189)	Btwn-subject SD
Light steps per day								
Work day								
Mean ± SD	7,700	7,300	6,600	± 3,900	7,200	5,600	6,200	± 3,900
Difference		-340	-1,000			-1,600	-990	
±99% CL		±2,700	±1600			±2,000	±1,400	
Inference		Trivial	Small↓**			Small↓**	Small↓**	
Non-work day								
Mean ± SD	7,600	6,800	6,400	± 3,000	7,000	6,300	7,100 <sup>†</sup>	± 4,000
Difference		-870	-1,300			-680	70	
±99% CL		±2,500	±1,500			±2,500	±1,700	
Inference		Small↓	Small↓**			Trivial	Trivial	
Moderate steps per day								
Work day								
Mean ± SD	2,900	2,300	3,700	± 2,300	2,200	3,100	3,900	± 2,200
Difference		-560	820			870	1,700	
±99% CL		±1,900	±1,100			±1,300	±920	
Inference		Small↓	Small↑**			Small↑**	Mod.↑**	
Non-work day								
Mean ± SD	2,200 <sup>†</sup>	2,300	3,000	± 1,900	1,600	1,700 <sup>†</sup>	3,500	± 1,400
Difference		100	800			120	1,900	
±99% CL		±2,200	±1,300			±1,700	±1,100	
Inference		Trivial	Small↑*			Trivial	Large↑**	
Total steps per day								
Work day								
Mean ± SD	10,600	9,600	10,300	± 5,000	9,400	8,800	10,100	± 4,800
Difference		-990	-270			-660	700	
±99% CL		±3,600	±2,100			±2,500	±1,800	
Inference		Small↓	Trivial			Trivial <sup>0</sup>	Trivial <sup>0</sup>	
Non-work day								
Mean ± SD	9,900	9,100	9,400	± 3,800	8,700	8,000	10,600 <sup>†</sup>	± 4,300
Difference		-770	-490			-700	1,900	
±99% CL		±3,700	±2,200			±3,100	±2,100	
Inference		Small↓	Trivial			Trivial	Small↑**	

Inferences are based on uncertainty in the difference in relation to the smallest important difference of 0.20 between-subject SD. Arrows indicate the direction of the difference from the group with a young child at home. Asterisks indicate inferential comparisons as follows: clear substantial difference at the \*90% and \*\*99% level, and clear trivial difference at the <sup>0</sup>90% and <sup>00</sup>99% level. All other differences are unclear. The magnitude of difference (difference in means divided by between-subject SD) was determined as follows: < 0.20, trivial; 0.20-0.59, small; 0.60-1.19, moderate (mod.); ≥1.20, large. <sup>†</sup> indicates clear substantial within-group differences at the 99% level between work days and non-work days.

**Table 10.** Differences in proportion (%) of time spent in sedentary, light, and moderate-to-vigorous intensities on work days and non-work days among men and women with and without children at home.

	Men			Women		
	Young child ( <i>n</i> = 73)	Older child ( <i>n</i> = 22)	No child ( <i>n</i> = 177)	Young child ( <i>n</i> = 99)	Older child ( <i>n</i> = 46)	No child ( <i>n</i> = 189)
Sedentary time						
Work day						
Mean ± <i>SD</i>	72.2 ± 9.8	73.0 ± 9.6	73.8 ± 9.4	71.0 ± 10	75.8 ± 9.2	75.4 ± 9.3
Diff; ±99% CL		0.8; ±6.9	1.5; ±4.1		4.8; ±5.2	4.4; ±3.7
Inference		Trivial	Trivial <sup>0</sup>		Small↑**	Small↑**
Non-work day						
Mean ± <i>SD</i>	72.3 ± 8.0	73.6 ± 7.8	74.5 ± 7.6	71.7 ± 7.9	74.5 ± 7.4	73.5 ± 7.6 <sup>†</sup>
Diff; ±99% CL		1.4; ±7.7	2.2; ±4.6		2.8; ±5.6	1.7; ±3.8
Inference		Trivial	Small↑*		Small↑*	Small↑*
Light-intensity activity						
Work day						
Mean ± <i>SD</i>	24.2 ± 8.6	24.0 ± 8.6	22.0 ± 8.1	26.2 ± 9.4	20.7 ± 8.1	20.3 ± 8.0
Diff; ± 99% CL		-0.2; ±6	-2.2; ±3.6		-5.5; ±4.8	-5.9; ±3.4
Inference		Trivial	Small↓**		Moderate↓**	Moderate↓**
Non-work day						
Mean ± <i>SD</i>	25.1 ± 7.2 <sup>†</sup>	23.4 ± 6.9	21.9 ± 6.6	26.4 ± 7.4	23.4 ± 6.9 <sup>†</sup>	22.5 ± 6.7 <sup>†</sup>
Diff; ±99% CL		-1.7; ±6.7	-3.2; ±4.0		-3; ±5.3	-3.9; ±3.5
Inference		Small↓	Small↓**		Small↓*	Small↓**
MVPA						
Work day						
Mean ± <i>SD</i>	1.7 ± 1.3	1.5 ± 1.1	2.3 ± 1.7	1.3 ± 1	1.8 ± 1.3	2.2 ± 1.7
Diff; ±99% CL		-0.2; ±0.9	0.6; ±0.5		0.5; ±0.5	0.9; ±0.4
Inference		Small↓	Small↑**		Small↑**	Moderate↑**
Non-work day						
Mean ± <i>SD</i>	1.1 ± 0.7	1.4 ± 0.8	1.4 ± 0.9 <sup>†</sup>	0.7 ± 0.4 <sup>†</sup>	0.9 ± 0.5 <sup>†</sup>	1.5 ± 0.8
Diff; ±99% CL		0.3; ±0.8	0.3; ±0.5		0.2; ±0.4	0.8; ±0.3
Inference		Small↑	Small↑*		Small↑	Large↑**

Inferences are based on uncertainty in the difference in relation to the smallest important difference of 0.20 between-subject *SD*. Arrows indicate the direction of the difference from the group with a young child at home.. Asterisks indicate inferential comparisons as follows: clear substantial difference at the \*90% and \*\*99% level, and clear trivial difference at the <sup>0</sup>90% and <sup>00</sup>99% level. All other differences are unclear. The magnitude of difference (difference in means divided by between-subject *SD*) was determined as follows: < 0.20, trivial; 0.20-0.59, small; 0.60-1.19, moderate; ≥1.20, large. <sup>†</sup> indicates clear substantial within-group differences at the 99% level between work days and non-work days.

## **Sedentary and light-intensity activity**

Adults with young children recorded approximately 4–4.5 hr of light-intensity activity per day and approximately 12 hr of sedentary time between the hours of 6 am and 11 pm (Table 8). On work days, women with young children spent proportionately more time in light-intensity activity (difference ~60 min per day) and less sedentary time than women with older children or no children (difference ~45 min per day); these women also recorded more light steps per day. On non-work days, the magnitudes of differences in light-intensity activity between women with and without young children were lower, and differences in light steps were unclear. Among men, differences in sedentary time were only observed on non-work days, with a small beneficial association of young children in sedentary time (difference ~22 min per day). Men with young children also recorded more light steps per day on both work days and non-work days, than men with no children.

## **Physical activity by type of day**

In the main analyses, differences in the magnitudes of effects were observed between work days and non-work days for some comparisons. Additional analyses by the type of day revealed that on non-work days women with young children spent less time in MVPA, women without children spent more time in light-intensity activity and less in sedentary time, men with young children spent more time in light-intensity activity, and men with no children spent less time in MVPA, than on work days (small effect sizes). All other results were trivial (Table 9 and Table 10; clear effects at 99% level marked<sup>†</sup>).

## **Discussion**

This study investigated the overall amount of physical activity, and proportion of time spent in sedentary time, light-intensity activity, and MVPA among adults with young children, adults with older children, and adults without children at home. Overall, there was little difference in the total accumulation of physical activity per day across groups for women or men, however differences were observed in the intensity at which activity was undertaken. Specifically, women with young children spent less time in MVPA (particularly on non-work days), more time in light-intensity activity, and less in sedentary time than women with no children. A similar pattern was observed for males, but differences in sedentary time were seen only on non-work days.

The effects of having a young child at home ranged from trivial to small among men and small to large among women; this denotes a greater effect of young children on women's physical activity than men. There is evidence to suggest that women spend more time and take more responsibility in the care of children, even among dual-income families,<sup>94,255,256</sup> which may influence associations with physical activity. Fewer women with young children in the present study were in paid work than men with young children, which may indicate greater time in the presence of young children.

Previous studies of self-reported physical activity have overwhelmingly shown that parents achieve less MVPA than adults without children.<sup>18,114,125</sup> The nature of self-report measures means that planned and sustained activities are likely to be recalled more easily and therefore unstructured activities may not be recalled, or recalled inaccurately. On the other hand, accelerometers offer the utility of capturing movement regardless of purpose, duration, or intensity so offer an ideal method for gaining a deeper understanding of the associations of young children with adults' physical activity. Results of recent studies of accelerometer-measured MVPA are conflicting,<sup>15,35</sup> most likely due to differences in the treatment of accelerometer data. One study analysed sustained MVPA bouts of  $\geq 10$  min;<sup>35</sup> their findings supported the self-reported evidence that MVPA was lowest among mothers with children < 6 years, however no effect was found for fathers with young children. On the other hand, the U.S. Neighborhood Quality of Life Study<sup>15</sup> included all minutes of MVPA and found no meaningful differences in MVPA between adults with children < 5 years, and those with no children or older children. Findings from the present study show the proportion of time spent in MVPA was lower among women with young children, and the magnitude of this difference was moderate on work days and large on non-work days. For men, small differences in MVPA were observed on work days and non-work days.

Previously only two studies have compared sedentary time of adults with and without young children.<sup>15,120</sup> Both studies analysed self-reported sitting time and found that having a young child (compared with no child) was associated with significantly lower sitting time in women<sup>15,120</sup> and men.<sup>15</sup> Published evidence of accelerometer-derived sedentary time is limited to a small sample of women with young children who participated in a validation study;<sup>146</sup> results showed

that these women recorded a mean of 7 h per day in sedentary time, although this estimate was not adjusted for hours-per-day wear-time.

No other published studies have reported light-intensity activity in adults with young children, however results from the present study show that adults with young children achieve greater levels of such activity than adults without children. It is evident from time-use studies that parents spend more time in household and caring activities than non-parents which may account for the increased level of light-intensity activity. This area of research is emerging and there is little evidence from others studies of light-intensity activity across different populations. Recently, Powell et al.<sup>73</sup> has argued that substantial variations exist in total energy expenditure from sedentary and light activity and greater emphasis is needed on understanding the health effects of these behaviours.

Current guidelines recommend at least 30 min of MPA on five or more days a week, undertaken in bouts of no less than 10 min, over and above light-intensity activities of daily living.<sup>80</sup> However, with limited opportunities for sustained and purposeful physical activity, parents are struggling to achieve this recommendation. The well-established links between MVPA and positive health outcomes are substantial, and regular participation in MVPA remains an important health promotion message for parents of young children. However, evidence is mounting to show that replacing sedentary time with light-intensity activity is also important for cardio metabolic risk reduction independent of time spent in MVPA.<sup>7,28,30,77</sup> As adults with young children in this study generally spent less time sedentary and more time in light-intensity activity than adults with no children, it is likely that the steady demands of caring for a young child results in the beneficial replacement of sedentary behaviour with light-intensity activity.

Although there is much interest in the dose-response relationship of physical activity, current knowledge is severely constrained by a lack of measurement of physical activity below the moderate-intensity threshold. What is widely acknowledged, however, is that some activity is better than none.<sup>73,257,258</sup> It is expected that different doses of activity at various intensities offer varying benefits for health;<sup>63,73,259</sup> seminal work by Hamilton and colleagues posited distinct physiological responses to sedentary behaviour, light-intensity activity, and MVPA.<sup>71,74</sup> Despite the emergent nature of these perspectives, evidence is mounting, and a growing number of

experts in the field are posing a complete health message: to sit less, move more, and exercise.<sup>72,81</sup>

Given the parameters faced by parents with young children, strategies to overcome and negotiate constraints around physical activity need to acknowledge what it means to be a parent and how physical activity fits in with that meaning. Parenthood generally results in increased activities of daily living and as such parents could be encouraged to reframe these activities as an opportunity for moving more and sitting less. Findings of this study also indicate that non-work days may present a target for promotion of MVPA. Integrating MVPA into family time may be an ideal strategy for parents during non-work days; for example, parents could be encouraged to engage in MVPA on non-work days by taking children to the park, beach, cycle path, or community centre and to be active alongside or together with their children. Not only will this be of benefit to parents, but integrating activity as a family may also promote an active family culture, positively influence children's physical activity,<sup>136</sup> and provide an opportunity for family connectedness.<sup>20,205</sup>

This cross-sectional study of both males and females utilised a robust multi-stage sampling design. This study was not specifically designed to measure physical activity among parents. As such presence of children in the household was used as a proxy indicator of parenthood and it is possible that some misclassification of parent subgroup may have occurred. Strengths of this study are the inclusion of both men and women, the use of an objective measure of physical activity, and the analysis of accelerometer data across all intensities, in particular the inclusion of sedentary and light-intensity activity. Although, sedentary time is identified arbitrarily using cut point thresholds and it is not possible to distinguish genuine sedentary behaviours (activities  $\leq 1.5$  METs in sitting or reclining posture<sup>93</sup>). Nevertheless sedentary time provides a useful indicator of time spent in activity at the lowest end of the intensity spectrum. Similarly, MVPA was estimated using non-standard count thresholds; although there is much debate surrounding count thresholds.<sup>260</sup> The selection of different count thresholds and criteria for valid days is likely to have an effect on cross-study comparability of activity estimates. Nonetheless, these procedures were standardised within this study therefore comparisons between groups and days, and thus the associations found in this study, are unlikely to be affected.

## Conclusions

Unlike previous studies focussing solely on the MVPA paradigm, this study provides a representation of activity performed across the full intensity spectrum by adults with young children, with important comparisons made with adults with older children and adults with no children. The presence of young children was associated with lower sedentary time and higher levels of light-intensity activity. On the other hand, those with young children spent proportionately less time in MVPA than those without children, particularly on non-work days. Health promotion messages for parents should focus on reframing daily parenting activities as opportunities for increasing physical activity, and integration of physical activity with family activities on non-work days.



### **Hour-by-hour physical activity profiles:**

#### **A study of adults with and without young children**

##### **Preface**

Findings from the previous chapter show that adults with young children accumulate substantial physical activity through light-intensity activity, which offsets time spent sedentary and in MVPA. Although adults with young children record some MVPA, it is unclear whether this occurs during specific periods or whether it is spread throughout the day. Furthermore, though qualitative and time-use studies consistently show that adults with young children are immersed in childcare and household activities there is little understanding of how this is reflected in patterns of sedentary and light-intensity activity throughout the day. Accordingly, this chapter addresses these gaps and describes the hour-by-hour physical activity profile of adults with and without young children, using accelerometer-derived physical activity at sedentary, light, and moderate-to-vigorous intensities. A novel approach to profiling physical activity is used, whereby the interrelations between physical activity at sedentary, light and moderate-to-vigorous intensities are simultaneously taken into account to describe the predominant behaviour pattern in each hour.

## Abstract

**Background:** Little is known about how physical activity at sedentary, light, and moderate-to-vigorous intensities interrelate throughout the day among adults with young children. The purpose of this study was to use a novel data treatment approach to describe hour-by-hour profiles of physical activity among adults with and without young children.

**Methods:** Accelerometer-derived physical activity from adults aged 20–39 years ( $n = 605$ ) were included in these analyses. Associations between the presence of young children in the household and (1) sedentary time and (2) MVPA during work hours and non-work hours were assessed using mixed models. Hourly observations of sedentary, light, and moderate-to-vigorous intensities were plotted for adults with and without young children, and the totality of physical activity per hour was explored using a novel profiling approach.

**Results:** There were distinct differences in the way physical activity was accumulated throughout the day between adults with and without young children. Women with young children displayed high levels of light-intensity activity across the whole day, whereas women without children displayed periods of high sedentary time during work hours and distinct peaks of MVPA outside work hours. Differences between men with and without young children were most apparent for MVPA outside work hours.

**Conclusions:** Although adults with young children may experience limited opportunities for sustained and purposeful MVPA, plentiful opportunities exist for light-intensity activity to replace otherwise sedentary time. Health promotion messages should acknowledge the totality of physical activity and the different profiles of physical activity behaviour.

## Background

Leading a physically active lifestyle is an essential element for optimal health and wellbeing, with substantial evidence to support the link between insufficient levels of physical activity and incidence of chronic disease and all-cause mortality.<sup>5,6</sup> Parents with young children are a population group that are regularly identified as not meeting current physical activity guidelines.<sup>18,122,141,183</sup> Research has shown that parents with young children have a distinct set of constraints that affect their autonomy for participation in purposeful physical activity;<sup>169</sup> parents cite lack of time due to responsibilities and childcare commitments as their main barrier to physical activity.<sup>17-19,169,188</sup> However, there have also been reports that parents with young children accumulate substantial physical activity through lifestyle activities, such as household and childcare activities.<sup>14,15,111</sup> Indeed, research findings have shown that adults with young children spend a greater proportion of the day in light-intensity activity than adults without children, with this light-intensity activity largely replacing sedentary time (see Chapter 5).

In recent years there has been growing interest in the health effects of physical activity below the moderate-intensity threshold as well as the adverse risk to health incurred through sedentary behaviour. In particular, sedentary behaviour is associated with risk for all-cause mortality,<sup>32-34</sup> cardiovascular disease,<sup>28</sup> some cancers,<sup>64</sup> and metabolic syndrome.<sup>30,31</sup> What is more, many of these associations have been shown to be independent of levels of MVPA.<sup>28,30,32,34,64,70</sup> It is becoming increasingly acknowledged that physical activity needs to be understood in totality, with reference to sedentary time, light-intensity activity, and MVPA, rather than one dimension alone. At present little is known of how sedentary time, light-intensity activity, and MVPA coexist within diverse profiles of physical activity behaviour. Some research has been conducted among traditional societies, such as the Old Order Amish community, which have shown extremely high levels of lifestyle activity and low incidence of chronic disease and obesity.<sup>261,262</sup> Other research has identified an 'active couch potato' phenomenon<sup>74,79</sup> where high levels of sedentary time are present even among those who attain recommended levels of activity. Furthermore, some women have been shown to accumulate over 80% of their physical activity through household-related activities, with stronger associations with mortality than leisure-time physical activity alone.<sup>151</sup> It is possible that current health promotion messages are too general and more specific messages are needed that address different physical activity

profiles. For example, current recommendations may not be relevant for populations such as the Old Order Amish community. More understanding is needed of the nuances of different profiles of physical activity, and how they relate to health, so that more relevant messages may be developed.

Developments in measurement technology—in particular minute-by-minute time-stamped data via accelerometers—have enabled within-day physical activity patterns to be examined. Although studies of this nature are limited at present, this technology offers an opportunity for deeper insights into the ways in which sedentary time, light-intensity activity, and MVPA coexist across the day, and how different profiles of physical activity accumulate physical activity in different ways. Time use studies show that adults with and without children allocate their time differently, with time for childcare largely replacing personal care time and free time, but there is little understanding of how this is reflected in patterns of sedentary and light-intensity activity throughout the day. The purpose of this study was to investigate the hour-by-hour patterns of physical activity on work days and non-work days in a sample of adults in order to understand the profiles of physical activity behaviour among those with and without young children.

## **Methods**

Data were drawn from the URBAN study, a multi-centre, stratified, cross-sectional study of physical activity in New Zealand adults and children.<sup>240</sup> Ethical approval to conduct the study was provided by the host institutions' ethics committees (AUTEC: 07/126, MUHECN: 07/045), and all participants provided written informed consent prior to participation.

## **Participants**

A total of 2,031 adults aged  $\geq 20$  years were recruited randomly from 48 neighbourhoods across four New Zealand cities between 2008 and 2010. Full details of neighbourhood selection, participant recruitment, and data collection procedures are described elsewhere.<sup>240</sup>

## **Assessment of physical activity**

Minute-by-minute physical activity was assessed via accelerometry over a seven-day period with hip-mounted Actical accelerometers (Mini-Mitter, Sunriver, OR). The units have been shown to be a reliable and valid measure of physical activity in adult populations.<sup>241,242</sup>

Participants were instructed to wear the accelerometers during waking hours for seven consecutive days. Periods of non-wear (zero counts > 59 contiguous minutes) were identified within the Statistical Analysis System (version 9.2; SAS Institute, Cary, NC) and set to missing.<sup>244</sup> A day was considered valid if it contained  $\geq 6$  hr of valid wear time. As described in detail previously (Chapter 5, methods section), hourly observations of accelerometer data were expressed as mean proportion of the number of minutes of recording per period (up to 60 min) spent in sedentary time (< 100 cpm), light-intensity activity (100-999 cpm), and MVPA ( $\geq 1,000$  cpm), and also as mean step counts per hour accumulated in light steps (< 1,000 cpm), moderate steps ( $\geq 1,000$  cpm), and total steps. Physical activity was analysed by type of day; work days included Monday to Friday, and non-work days were specified as weekend days and any public holiday during participants' measurement period.

### **Children in the household**

Participants completed a computer-assisted personal interview with a trained interviewer and reported details on household composition, including the ages of all children aged < 18 years residing in the dwelling during the seven-day period prior to interview. Participants were partitioned into three sub-groups: those with any child aged < 5 years (hereafter young child), those with any child aged 5–12 years and no child aged < 5 years (hereafter older child), and those without any child aged < 13 years (hereafter no child).

### **Statistical analysis**

Participants with at least one valid day of accelerometer data were partitioned into low (20–39 years), mid (40–52 years), and high (52–70 years) age tertiles based on even distribution across the study sample. For the analysis of the effect of young children in the household only those participants in the low age tertile were included ( $n = 605$ ); New Zealand age-specific fertility rates in 2010 were highest among those aged 30–34 years, followed by 25–29 years, and 20–24 years, with a rapid decline from 40 years.<sup>105</sup>

Separate analyses were performed for hourly observations of light steps, moderate steps, and all steps using the mixed model (Proc Mixed) in SAS, and analyses of proportions using the generalised mixed model (Proc Glimmix). These analyses are described in detail in Chapter 5 (statistical analysis section), and were conducted separately for males and females for work






days and non-work days. In brief, fixed effects in the models included city, maximum daily temperature, daily rainfall, and presence of children in the household. Random effects included identity of the participants, the interactions of participant identity with identity of the hour and identity of the day, and the residual. The above analyses were also performed separately for work hours (9 am–5 pm) and non-work hours (7–9 am and 5–7 pm) on work days.

An inference about the true value of a given effect (a difference in means) was based on its uncertainty in relation to the smallest important difference, which was determined by standardisation as 0.20 of the pure between-subject standard deviation within the two compared subgroups;<sup>40</sup> this standard deviation was derived from the random effect for the identity of the participants in the mixed model. Inferences were non-clinical: an effect was deemed unclear if the 90% confidence interval included the smallest important positive and negative differences; the effect was otherwise deemed clear. Effects that were clear with the more conservative 99% confidence interval are also indicated. The magnitude of a given clear effect was determined from its observed standardised value (the difference in means divided by the between-subject standard deviation) using the following scale: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate;  $\geq 1.20$ , large.<sup>40</sup>

### ***Hour-by-hour activity profiles***

Daily activity profiles of the three children-in-the-household subgroups (young children, older children, no children) generated by the mixed models contained model-adjusted mean levels of physical activity variables (light, moderate, and total steps; and proportion of time spent in sedentary, light, and moderate-to-vigorous intensities) per hourly period. The hourly means for each physical activity variable were collated across days and sexes, and quartiles were calculated. Quartiles were used to derive an activity classification based on the contribution of sedentary, light, and moderate-to-vigorous intensities during that period (Table 11); for each sub-group, hourly periods on work days and non-work days were classified according to these criteria. A table of physical activity outcome variables by hour used to derive classifications, is provided in Appendix F.

**Table 11.** Step-wise classification of hour-by-hour activity profiles.

Step	Classification	Icon	Criteria
1	High MVPA		$\geq 2.2\%$ MVPA and $\geq 219$ moderate steps per hour and $< 72\%$ sedentary
2	High MVPA and high sedentary		$\geq 2.2\%$ MVPA and $\geq 219$ moderate steps per hour and $\geq 72\%$ sedentary
2	High sedentary		$\geq 72\%$ sedentary or $< 440$ total steps per hour
3	High physical activity and Low sedentary		$\geq 28\%$ light-intensity and $\geq 477$ light steps per hour or $\geq 24\%$ light-intensity and $\geq 1.6\%$ MVPA
4	Low physical activity and Low sedentary		All else

Criteria were determined by quartile ranges (25<sup>th</sup> percentile = Q<sub>1</sub>, 50<sup>th</sup> percentile = Q<sub>2</sub>, 75<sup>th</sup> percentile = Q<sub>3</sub>): Sedentary Q<sub>2</sub> = 72%; Light Q<sub>2</sub> = 24%, Q<sub>3</sub> = 28%; MVPA Q<sub>2</sub> = 1.6%, Q<sub>3</sub> = 2.2%; Light steps Q<sub>3</sub> = 477; Moderate steps Q<sub>3</sub> = 219; Total Steps Q<sub>1</sub> = 440. Hourly periods were classified step-wise.

## Results

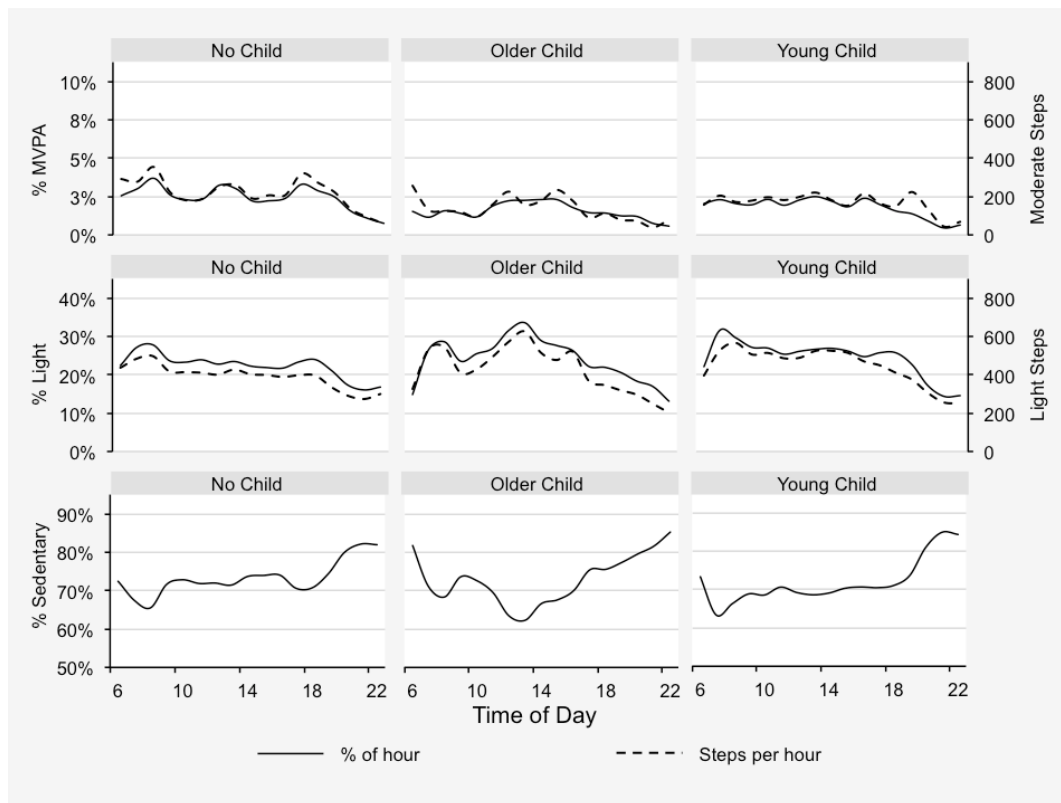
A total of 605 adults in the low age tertile (20–39 years) were included in these analyses (Table 8). On average, adults provided 6 days (*SD* 2, range 1–9 days) of valid data. Average daily wear time for each participant was 13 h (*SD* 1.8, range 6–16 h).

### Hour-by-hour physical activity

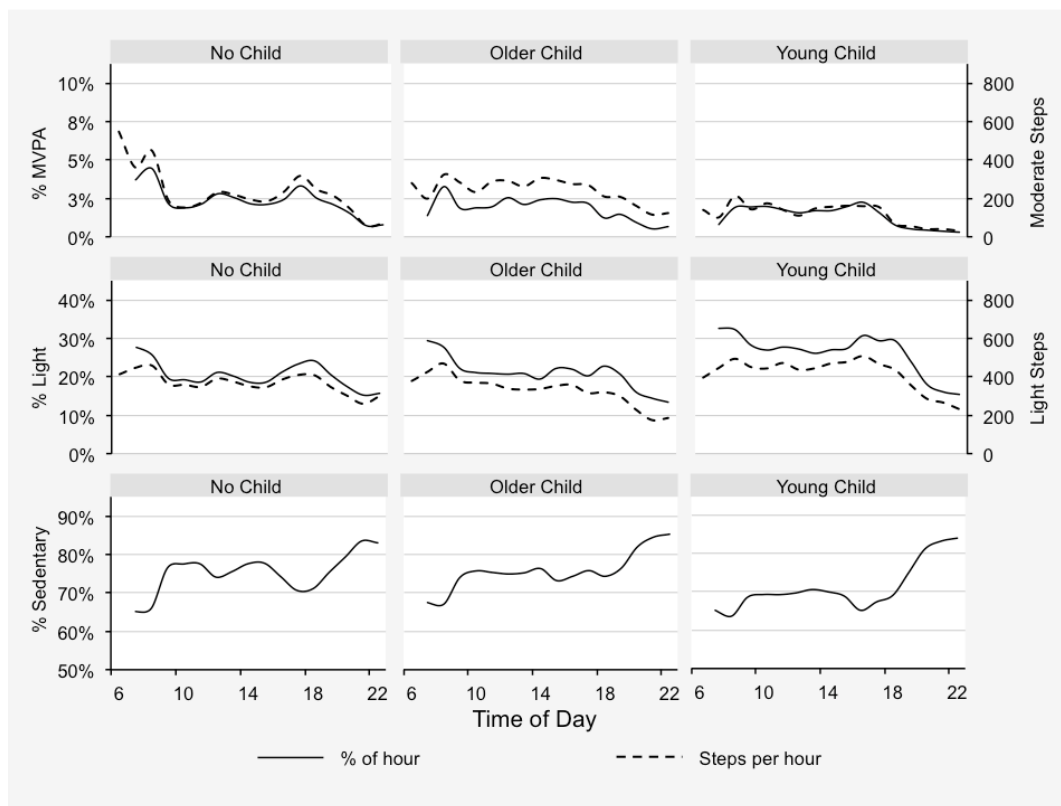
#### Work days

The mean hour-by-hour levels of physical activity are shown in Figure 6 for men and Figure 7 for women. On work days, men and women with young children displayed high levels of light-intensity activity in the early morning (7–9 am), and also in the late afternoon among women (3–7 pm). Proportion of time spent sedentary increased rapidly throughout the evening, from 7 pm, with concurrent decreases in light-intensity activity. Levels of MVPA were moderate for most of the day until 6 pm among men with young children, however MVPA was generally low in women with young children with slight elevations MVPA occurring 9–11 am and 3–5 pm.

Differences in the patterns of activity between women with and without young children were apparent from 7 am until 8 pm. In particular, women with young children did not show the same peaks of MVPA during the periods before work, after work, and during the lunch hour as women without children, and—to a lesser extent—women with older children. Conversely, women with young children were less sedentary than women without children during work hours. It appears that for women with young children, this sedentary time is replaced with a greater proportion of



**Figure 6.** Mean hour-by-hour physical activity for men on work days



**Figure 7.** Mean hour-by-hour physical activity for women on work days



time spent in light-intensity activity across the whole day. From 8 pm a predominance of sedentary time was evident for all women, with or without children. Likewise, differences between men with and without young children were most apparent for MVPA during the early morning, midday, and late afternoon periods. Periods of increased light-intensity activity occurred around 7 am to 9 am on work days for men with young children; however sedentary time was similar for much of the day, peaking during the evening. These figures show clearly the structure of the working day among those without children, with periods of higher MVPA during the before and after work periods. These patterns were confirmed by the mixed model analyses undertaken separately for work hours and for non-work hours (Table 12). The magnitude of the differences in sedentary time between women with young children and women with no children were greatest during work hours (difference ~36 min); differences in MVPA were greatest during non-work hours (difference ~4 min). Similar patterns were observed among men, albeit smaller magnitudes of effect.

### ***Non-work days***

Observed patterns of physical activity for women with young children were similar for work days and non-work days, however type-of-day differences were seen among the other groups (Figure 8 and Figure 9). Both men and women with young children showed high levels of light-intensity activity throughout the day. MVPA levels were consistently low among women, however men with young children had small peaks in the late morning and late afternoon. In contrast, women without children had moderately high levels of MVPA throughout the whole day; men without children also had moderately high levels of MVPA from 10 am to 5 pm. All groups showed steady increases in sedentary time throughout the afternoon and into the evening.

### **Activity Profiles**

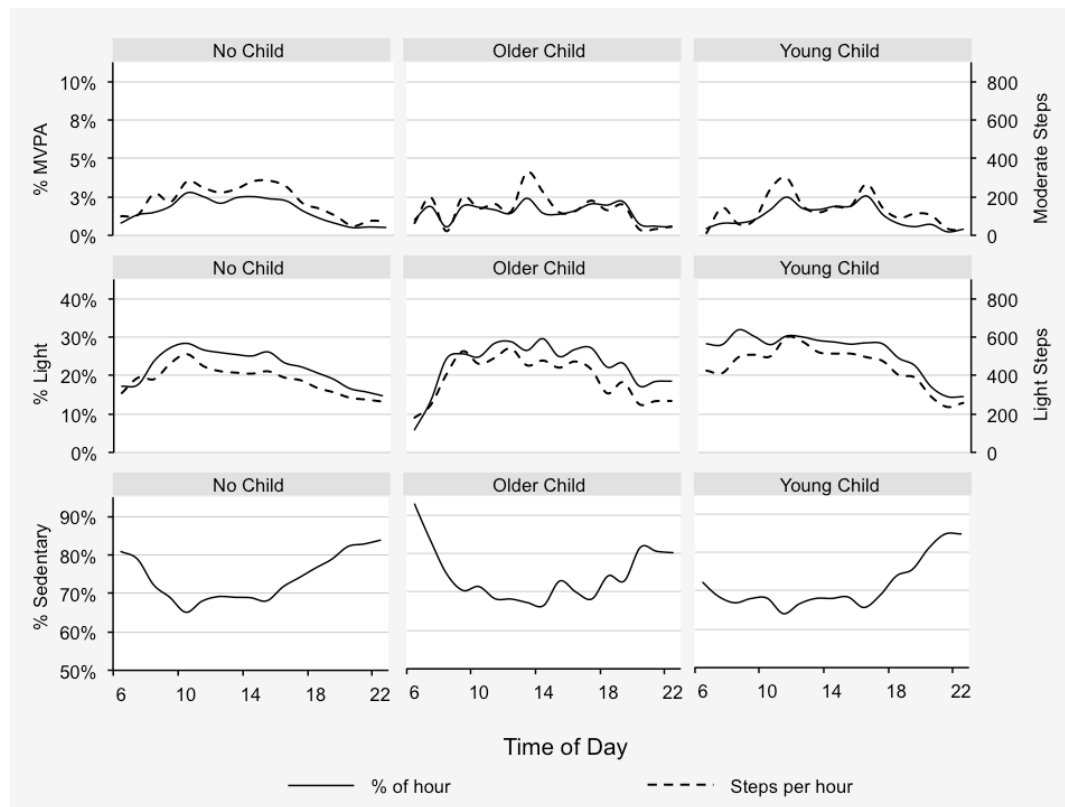
Hour-by-hour physical activity profiles for all groups are presented in Figure 10 for work days and non-work days. These figures summarise the relationship between sedentary time, light-intensity activity, and MVPA, as well as light, moderate, and total steps, to provide an indication of the predominant behaviour occurring during each hour. Distinct profiles of behaviour were observed between those with and without young children. Those with young children show a low sedentary—low MVPA profile representative of lifestyle activity, whereas on work days

those without children show a divergent sedentary—MVPA profile, previously termed *active couch potatoes*.<sup>79</sup>

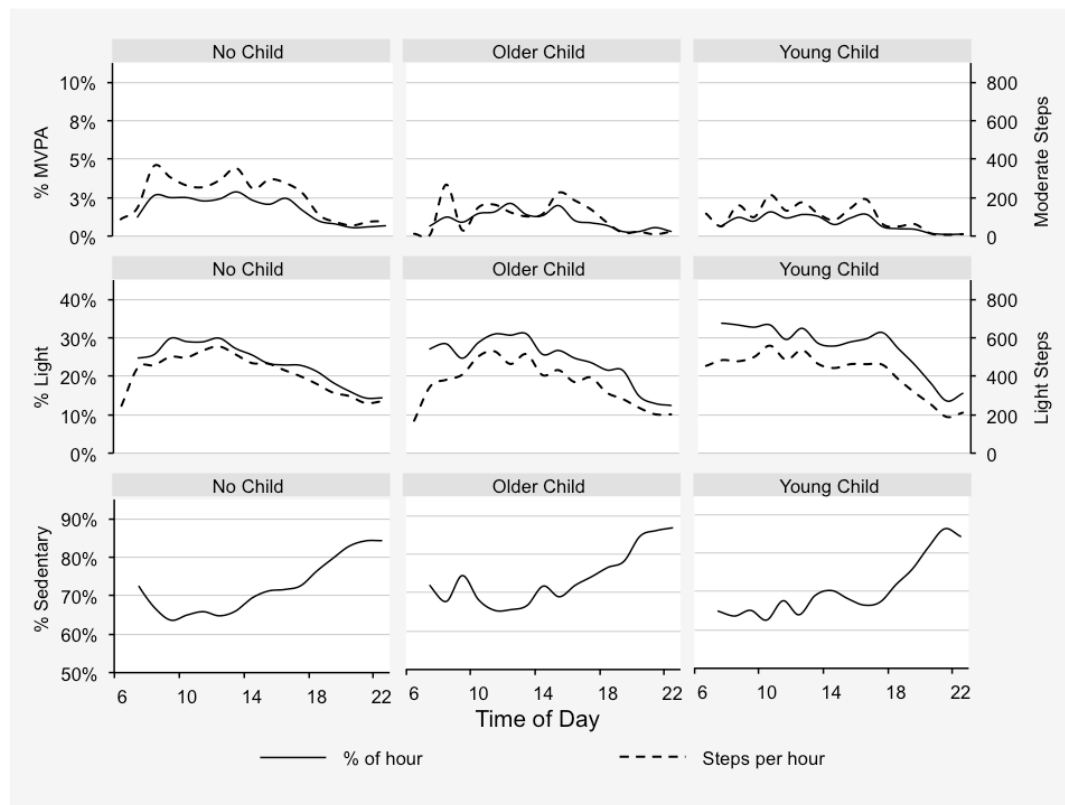
**Table 12.** Differences in proportion (%) of time spent in sedentary, light, and moderate-to-vigorous intensities during work hours and non-work hours on work days among men and women with and without children at home.

	Men			Women		
	Young child (n = 73)	Older child (n = 22)	No child (n = 177)	Young child (n = 99)	Older child (n = 46)	No child (n = 189)
Sedentary time						
Work hours						
Mean ± SD	69.7 ± 13.0	68.3 ± 13.0	72.9 ± 12.0	69.1 ± 13.0	74.7 ± 11.0	76.6 ± 11.0
Diff; ±99% CL		-1.4; ±9.2	3.2; ±5.4		5.6; ±6.4	7.4; ±4.6
Inference		Trivial	Small↑**		Small↑**	Moderate↑**
Non-work hours						
Mean ± SD	69.5 ± 9.1	74.7 ± 8.1	69.9 ± 9	67.5 ± 10	72.1 ± 9.6	69.7 ± 10
Diff; ±99% CL		5.3; ±7.6	0.4; ±4.5		4.7; ±6.0	2.2; ±4.3
Inference		Moderate↑*	Trivial		Small↑**	Small↑**
Light-intensity activity						
Work hours						
Mean ± SD	25.9 ± 12.0	27.7 ± 12.0	22.6 ± 11.0	27.5 ± 12.0	21.2 ± 9.9	19.4 ± 9.3
Diff; ± 99% CL		1.8; ±8.0	-3.3; ±4.7		-6.2; ±5.9	-8; ±4.2
Inference		Trivial	Small↓**		Small↓**	Moderate↓**
Non-work hours						
Mean ± SD	26.6 ± 7.7	22.6 ± 6.9	24.6 ± 7.3	29.7 ± 9.3	23.8 ± 8.1	24.3 ± 8.2
Diff; ±99% CL		4.0; ±6.4	2; ±3.8		-5.8; ±5.3	-5.4; ±3.8
Inference		Small↑*	Small↑*		Moderate↓*	Moderate↓**
MVPA						
Work hours						
Mean ± SD	2.1 ± 1.8	1.9 ± 1.6	2.5 ± 2.1	1.8 ± 1.5	2.1 ± 1.7	2.2 ± 1.8
Diff; ±99% CL		-0.2; ±1.3	0.4; ±0.8		0.2; ±0.8	0.4; ±0.6
Inference		Trivial	Small↑*		Trivial	Small↑**
Non-work hours						
Mean ± SD	1.6 ± 1.2	1.4 ± 1.0	2.8 ± 1.9	0.92 ± 0.7	1.7 ± 1.3	2.7 ± 2.0
Diff; ±99% CL		-0.2; ±1.1	1.1; ±0.6		0.8; ±0.5	1.8; ±0.3
Inference		Trivial	Mod.↑**		Mod.↑**	Large↑**

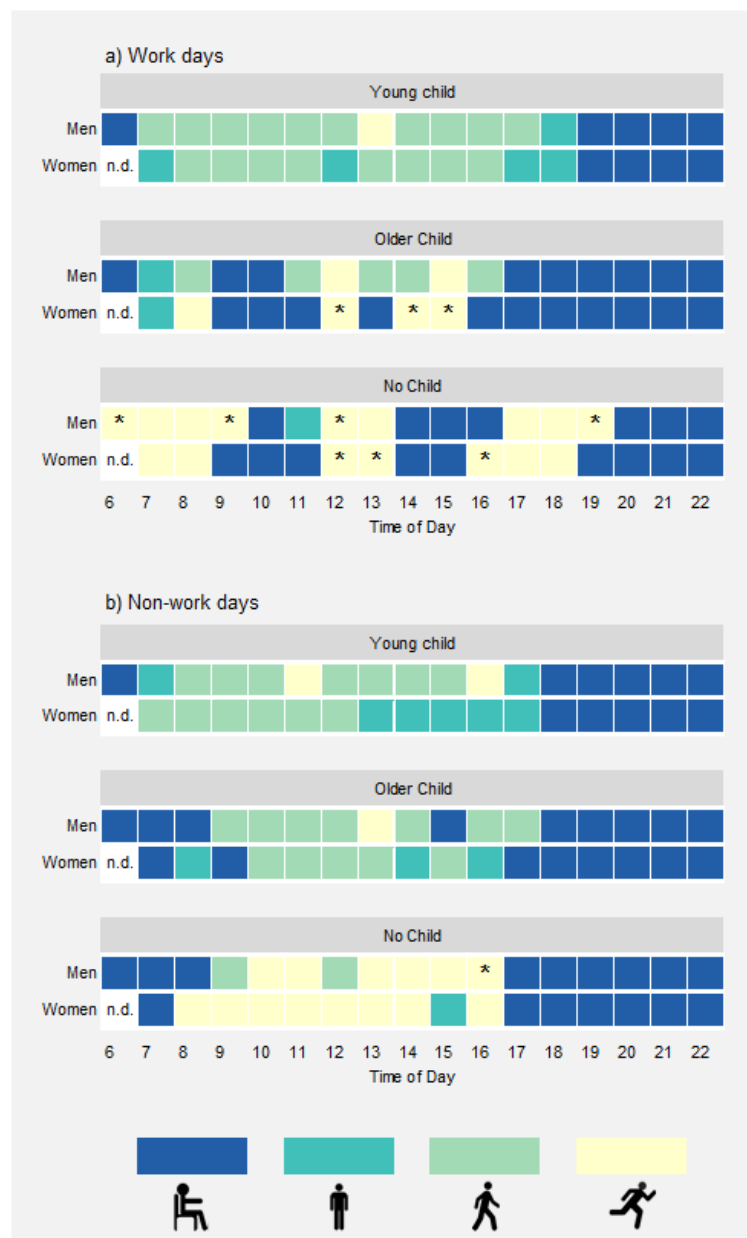
Inferences are based on uncertainty in the difference in relation to the smallest important difference of 0.20 between-subject *SD*. Arrows indicate the direction of the difference from the group with a young child at home. Asterisks indicate inferential comparisons as follows: clear substantial difference at the \*90% and \*\*99% level, and clear trivial difference at the <sup>0</sup>90% and <sup>00</sup>99% level. All other differences are unclear. The magnitude of difference (difference in means divided by between-subject *SD*) was determined as follows: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate (mod.); ≥ 1.20, large. † indicates clear substantial within-group differences at the 99% level between work days and non-work days.



**Figure 8.** Mean hour-by-hour physical activity for men on non-work days



**Figure 9.** Mean hour-by-hour physical activity for women on non-work days



**Figure 10.** Hour-by-hour physical activity profile for men and women on a) work days and b) non-work days. Each hourly period represents the totality of physical activity during that period (sedentary, light-intensity, and moderate-to-vigorous intensity). Activity classifications were derived from quartiles for each physical activity variable and were classified step-wise. 1) high MVPA and low sedentary (♻️); 2) high MVPA and high sedentary (♻️\*); 3) high sedentary (♻️); 4) high physical activity and low sedentary (♻️); and 5) low physical activity and low sedentary (♻️). n.d. = no data; \* = hourly periods with concurrent high MVPA and high sedentary values.

## Discussion

The purpose of this study was to examine hour-by-hour patterns of physical activity among adults to understand variations in the nature of physical activity behaviour throughout the day of those with and without young children. There were obvious distinctions in the patterns of

physical activity observed in those with young children and those without. A lifestyle activity profile was exhibited among those with young children characterised by low sedentary time, and high light-intensity activity throughout the day. On the other hand, those without children displayed a physical activity profile representative of active couch potatoes,<sup>79</sup> with high levels of sedentary time offset with distinct periods of MVPA. These results highlight the distinct profiles of physical activity that exist within different populations. There were obvious differences in how physical activity was structured throughout the day for those with and without young children. Adults without children showed clear patterns consistent with a 9 am to 5 pm working day, with increased sedentary time within these hours and peaks of MVPA occurring outside these hours. On the other hand, men and women with young children showed elevated periods of light-intensity activity across the whole day from 7 am to 7 pm.

These results indicate that while adults without children are somewhat constrained during work hours, with higher levels of sedentary time, the periods before work, at lunch, and after work offer opportunities for participation in leisure-time physical activity. Similar work-related patterns have been observed in other studies among Swedish adults,<sup>88</sup> and normal, overweight, and obese adults.<sup>87</sup> However, this does not seem to be the case for adults with young children. For those with young children, the early morning period is characterised by high levels of light-intensity activity, which most likely coincides with periods of high involvement in active childcare. This pattern is observed for both men and women, which possibly indicates joint parental care. Between 9 am and 5 pm, women with young children continue to have high levels of light-intensity activity, with lower sedentary time than those without children. Around half of women with young children in this sample were not in paid employment, presumably due to a caregiving role, thus it is likely that these patterns reflect participation in childcare and household activities of daily living. Men with young children also show higher levels of light-intensity activity and lower sedentary time between 9am and 5 pm than those without children, albeit to a slightly lesser degree than women. However, more men with young children were in paid employment than were men with no children; as such these patterns are somewhat perplexing. It is possible that men with young children may adopt flexible working arrangements; for example, the 2009 New Zealand Childcare Survey of 6,326 parents reported that 31% of fathers of children aged 0–13 years worked during evenings, 31% did weekend work, and 30% adopted flexible working hours.<sup>263</sup>

Another distinct peak in light-intensity and moderate peak in MVPA occurred during the late afternoon period in women with young children, which is also likely to reflect a period of high involvement in childcare. Interestingly, a recent study profiled hour-by-hour levels of sedentary time and MVPA of three- to five-year-old children.<sup>90</sup> This study showed the highest levels of MVPA in pre-schoolers occurred during the late afternoon period, from 4 pm to 6 pm. As similar patterns were observed in this study, this may offer an ideal period for promotion of family-integrated physical activity, where parents are encouraged to participate alongside or with their child.

The time costs of children have been extensively studied from a time-use perspective and it is clear that men and women with children spend more time in total work (paid work and unpaid work) than adults without children,<sup>94</sup> leaving little free-time available. Childcare and household activities (unpaid work) begin once a child rises in the morning (typically between 6:30 am and 7:00 am<sup>a</sup>) and continue until bed time (typically between 7:30 pm and 8:00 pm<sup>a</sup>). This is congruent with results in this study that indicate high levels of light-intensity activity and low sedentary time from 7 am until 7 pm among women with young children. Furthermore, the responsibility for supervision and care of children has important ramifications for autonomy over decisions to engage in purposeful physical activity. Indeed, data from a recent time use study demonstrated that women with young children spent almost 20 hr per day, on average, in active and passive childcare, and over 12 hr per day by men (including sleep).<sup>100</sup> For a parent to engage in purposeful physical activity away from their children, alternative supervision must be arranged. This in-turn raises ideological constraints such as entitlement beliefs and an ethic of care, where parents (in particular mothers) place the needs of others before their own.<sup>16,17</sup>

To date very little attention has been given to opportunities that are present within everyday living for parents, such as through household work and family integrated activities. Other studies have shown that adults with young children achieve higher levels of physical activity through household and caring activities than those without children,<sup>14,15</sup> and that more women with children met physical activity guidelines through daily living activities than women without children.<sup>111</sup> Integration of leisure-time physical activity with children through play and other

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<sup>a</sup> Mean rise time and bedtime of New Zealand and Australian children aged 0–3 years<sup>264</sup>

family activities has also been acknowledged as an important source of physical activity.<sup>136,159,160</sup> Indeed, it is clear from this study that women with young children achieve high levels of lifestyle activity throughout the whole day. Given the constraints faced by parents and the substantial opportunities present throughout activities of daily living, health promotion messages that acknowledge the totality of physical activity may be a more realistic, effective, and sustainable option for parents.

This cross-sectional study of both men and women utilised a robust multi-stage sampling design. As this study was not specifically designed to measure physical activity among parents, presence of children in the household was used as a proxy indicator of parenthood; it is possible that some misclassification of parent subgroup may have occurred. Strengths of this study are the inclusion of both men and women, the use of an objective measure of physical activity, and utilisation of the time-stamped nature of accelerometer data to explore hour-by-hour profiles of physical activity and sedentary time. Although, sedentary time is identified arbitrarily using standard cut point thresholds and it is not possible to distinguish genuine sedentary activities (activities  $\leq 1.5$  METs in sitting or reclining posture<sup>93</sup>). Nevertheless, sedentary time provides a useful indicator of time spent in activity at the lowest end of the intensity spectrum. Similarly, MVPA was estimated using non-standard count thresholds, although there is much debate surrounding count thresholds.<sup>260</sup> The selection of different count thresholds and criteria for valid days is likely to have an effect on cross-study comparability of activity estimates. Nonetheless, these procedures were standardised in this study therefore comparisons between groups and hours, and thus the associations found in this study, are unlikely to be affected.

## Conclusions

This study clearly shows distinct differences in the way physical activity is accumulated throughout the day between adults with and without young children. Although adults with young children may experience limited opportunities for sustained and purposeful MVPA, plentiful opportunities exist for light-intensity activity to replace otherwise sedentary time. Health promotion messages should acknowledge the totality of physical activity and the different profiles of physical activity behaviour.

## **Chapter 7**

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### **Patterns of physical activity and sedentary time:**

#### **A study of adults with and without young children**

#### **Preface**

The outcomes of Chapters 5 and 6 indicate that adults with young children engage in substantial light-intensity activity right throughout the day, offsetting sedentary time and MVPA. To further understand the complete profile of physical activity behaviour among adults with young children, it is also important to consider the manner in which physical activity and sedentary time are accumulated. It is understood that frequent interruptions of sedentary time with light-intensity activity is beneficial for health, and physical activity guidelines recommend that bouts of MVPA should be sustained for at least 10 min. The purpose of this study is to investigate the patterns of physical activity and sedentary time, in terms of the frequency and duration of bouts, among adults with and without young children. The findings from this study will contribute significantly to understanding of parents' physical activity behaviours, in terms of the frequency and duration dimensions of physical activity and sedentariness.



## Abstract

**Objective:** Examine differences in patterns of physical activity and sedentary time between adults with and without young children.

**Methods:** Accelerometer-derived physical activity from adults aged 20–39 years ( $n = 605$ ) were included in these analyses. Bouts of time in sedentary and moderate-to-vigorous intensities were identified and the mean frequency and duration of bouts were determined. Associations of young children in the household on patterns of physical activity accumulation were assessed using a generalised mixed model.

**Results:** Men and women with young children recorded shorter mean bout durations of MVPA (1.9 min–2.2 min) than adults without young children (2.5–3.0 min). Sedentary bouts were more frequent and of shorter mean duration among adults with young children (11.4–13.9 min) than adults with no children (15.7–17.8 min). The proportions of both sedentary and moderate-to-vigorous bouts sustained for > 10 min were smaller among adults with young children than adults with no children.

**Conclusions:** Adults with young children displayed an intermittent pattern of physical activity accumulation. Having young children in the household presents a positive environment for minimising prolonged sedentary time.

## Background

Parents of young children face unique constraints and parameters that influence their decisions and abilities to engage in purposeful forms of physical activity.<sup>16,17,20,167</sup> Studies have shown that parents are less active than they were prior to parenthood<sup>121</sup> and less active than their childless counterparts.<sup>18</sup> Emphasis has been placed on negotiating structural and ideological constraints in order to achieve adequate physical activity levels. However, given the complexities of ideological constraints<sup>16</sup> it is worthwhile to examine strategies to increase physical activity and reduce sedentary time within these parameters. To do so, it is important to understand how adults with young children use their time and consider how this may influence the manner in which activity is accumulated.

Time use studies show that parents allocate their time differently to adults without children. In general, a substantial portion of the day is allocated to childcare (including physical care, playing, teaching, and supervising)<sup>94,102</sup> and parents spend more time on household work (including meal preparation, cleaning, laundry, and grounds and home maintenance) than other adults.<sup>94</sup> A number of these childcare and household activities have been shown to be of moderate-intensity (3–6 METs).<sup>153,265-267</sup> In recent studies, parents reported more household-related moderate-intensity physical activity than non-parents.<sup>15,251</sup> Time spent undertaking childcare and household activities may also replace time spent in otherwise sedentary activities, with time for childcare and household work redirected primarily from paid work and sleep.<sup>94</sup>

Time use studies also show that a large amount of time spent on childcare is undertaken as a simultaneous activity.<sup>95</sup> This is congruent with the central notion of mothering as an enfolded activity, where multiple tasks require attention simultaneously.<sup>97,154,163-165</sup> This type of enfolded activity can result in frequent interruptions and changes in tasks due to the needs of a child.<sup>165</sup> Taken together, this suggests that parents may spend more of their time in intermittent lifestyle activities than nonparents. However, there is a lack of understanding whether this is reflected by intermittent patterns of physical activity and sedentary time among parents.

Two distinct elements of physical activity epidemiology have emerged: that which involves purposeful sustained activity at a moderate-to-vigorous intensity, and the other of intermittent non-exercise activity to break up sedentary time. Specifically, current guidelines for adequate

physical activity recommend a minimum of 150 min of moderate-intensity activity to be performed in bouts of at least 10 min duration throughout the week.<sup>42</sup> On the other hand, evidence suggests that sedentary time is independently associated with health, particularly the way in which it is accumulated.<sup>31,66,268</sup> As such, optimal human movement would include sustained bouts of MVPA, frequent breaks in sedentary time, and replacement of sedentary time with light-intensity activity.<sup>268</sup> The purpose of this study, therefore, was to investigate the patterns of physical activity and sedentary time among adults with young children (< 5 years), using time-stamped accelerometer data. Variations in movement patterns between those with young children, older children, and no children were also examined.

## **Methods**

Data were drawn from URBAN study, a multi-centre, stratified, cross-sectional study of associations between physical activity, health and the built environment in adults and children residing in New Zealand.<sup>240</sup> Ethical approval to conduct the study was provided by the host institutions' ethics committees (AUTEC: 07/126, MUHECN: 07/045).

### **Participants and recruitment**

Participants were recruited randomly from 48 selected neighbourhoods (stratified by high–low walkability, high–low Māori population) across four New Zealand cities. Data were collected between April 2008 and September 2010. Full details of neighbourhood selection, participant recruitment, data collection, and sample size calculations are described elsewhere.<sup>240</sup> In brief, a door-to-door recruitment strategy was utilised, where every *n*th household within each neighbourhood was sampled. One adult aged 20–65 years from each household was randomly selected (using next birthday enumeration) and invited to participate. Eligibility criteria were within the age range, English speaking, able to walk without aids (for physical activity measurement), and having resided in the household at least three months prior to, and for the week during, the measurement period.

### **Measures**

On the recruitment visit, trained interviewers gained written informed consent and delivered accelerometers and travel logs. Eight days later, the interviewer returned to the home to collect

the accelerometer and travel log, measure participants' height, weight, waist, and hip circumferences. Participants also completed a 40 min computer-assisted personal interview with a trained interviewer that assessed individual and household demographics, neighbourhood perceptions and preferences, physical activities, and sitting time. Measures specific to the current study only are detailed below.

*Physical Activity:* Objective measures of participants' physical activity were recorded using hip-mounted Actical accelerometers (Mini-Mitter, Sunriver, OR). The units have been shown to be a reliable and valid measure of physical activity in adult populations.<sup>241,242</sup> Participants were instructed to wear the accelerometer units during waking hours for 7 consecutive days. The units were set to record physical activity in 1 min epochs.

*Children in household:* Participants reported the ages of all children aged < 18 years residing in the dwelling during the 7 day period prior to survey completion.

*Demographic information:* Participants reported their sex, date of birth, ethnicity, combined household income, employment status, and marital status. Age was calculated from the date of birth as at the date of survey collection.

## **Data treatment**

Actical export files (Version 02.10) of raw accelerometer data for each participant were read into and plotted within the Statistical Analysis System (version 9.2; SAS Institute, Cary, NC) for checking. Device event markers and information derived from the compliance log were checked and matched against the accelerometer plots to determine valid wear time. Zero counts for > 59 contiguous minutes were categorised as non-wear time and set to missing.<sup>244</sup> It has previously been testified that application of stringent wear-time criteria may introduce bias to the study, whereby wear compliance may be correlated with physical activity levels.<sup>37,194</sup> As such any day that had a minimum of 6 h wear-time was considered a valid day.

Count thresholds of < 100 cpm defined sedentary time<sup>253</sup> and  $\geq 1,000$  cpm defined MVPA. The MVPA threshold was determined by best-fit of data simulations (unpublished data) using the Crouter 2R equations.<sup>254</sup> Accelerometer data were reduced to hourly summaries (0600–2259 hours; 17 periods); each hourly observation was then weighted by the number of recorded

minutes. Bouts of sedentary time were identified as > 1 contiguous minutes of < 100 cpm. MVPA bouts were defined as > 1 contiguous minutes of  $\geq 1,000$  cpm, with an allowance of 1 min below the threshold (1,000 cpm) for every 10 min above the threshold. Bouts were allocated to the hourly period in which the mid-point of the bout occurred. Variables were expressed as mean frequency of bouts per period and as mean duration of all bouts.

For the analysis of the effect of children in the household, participants were partitioned into three groups: those with any child aged < 5 years (hereafter young child), those with any child aged 5–12 years and no child aged < 5 years (hereafter older child), and those without any child aged < 13 years (hereafter no child). Work days included Monday to Friday and non-work days were specified as weekend days and any public holiday during participants' measurement period. Individual adult income was derived as the average of the combined household income by the number of adults living in the household. Age at the date of survey collection was categorised into low (20–39 years), mid (40–52 years), and high (52–70 years) tertiles based on even distribution across the whole study sample. New Zealand age-specific fertility rates in 2010 were highest among those aged 30–34 years, followed by 25–29 years, and 20–24 years, with a rapid decline from 40 years.<sup>105</sup> As such, analyses were performed for participants in the low age tertile only.

## **Statistical analysis**

Separate analyses were performed for the frequency and duration of sedentary bouts and of MVPA bouts using a generalized mixed model (Proc Glimmix) in SAS. The fixed effects in the mixed models included main effects to adjust for city (four levels), maximum daily temperature (numeric), and daily rainfall (two levels, presence or lack of rain). Random effects were included in the model to account for repeated measurement from day to day; the effects were the identity of the participants, the interactions of their identity with identity of the day, and the residual. The log link function and the Poisson distribution were invoked with an over-dispersed residual to account for any clustering of bouts of activity.

Each of the above analyses was performed separately for males and females in each of the three children-in-the-household groups on work days and non-work days. Mean levels of bouts and effects on bouts are shown as mean frequency of bouts in an average hour and as mean

duration of all bouts. Uncertainty (standard error) in the differences in the means of the children-in-the-household groups was derived by combining the standard errors of the group means.

An inference about the true value of a given effect (a difference in means) was based on its uncertainty in relation to the smallest important difference, which was determined by standardisation as 0.20 of the pure between-subject standard deviation within the two compared subgroups;<sup>40</sup> this standard deviation was derived from the random effect for the identity of the participants in the mixed model. Inferences were non-clinical: an effect was deemed unclear if the 90% confidence interval included the smallest important positive and negative differences; the effect was otherwise deemed clear. Effects that were clear with the more conservative 99% confidence interval are also indicated. The magnitude of a given clear effect was determined from its observed standardised value (the difference in means divided by the between-subject standard deviation) using the following scale: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate;  $\geq 1.20$ , large.<sup>40</sup>

## Results

### Participants

A total of 2,013 adults, mean age 46 years (*SD* 12), participated in the URBAN study between April 2008 and September 2010 (response rate 44%). Analyses were performed for participants in the low age tertile only ( $n = 605$ ). Figure 5 demonstrates the flow of participant recruitment and inclusion. Demographic characteristics of the adults included in these analyses are shown in Table 8. On average, adults in the low age tertile provided 6 days (*SD* 2, range 1–9 days) of valid data and daily wear time for each participant was 13 h (*SD* 1.8, range 6–16 h).

### Patterns of physical activity

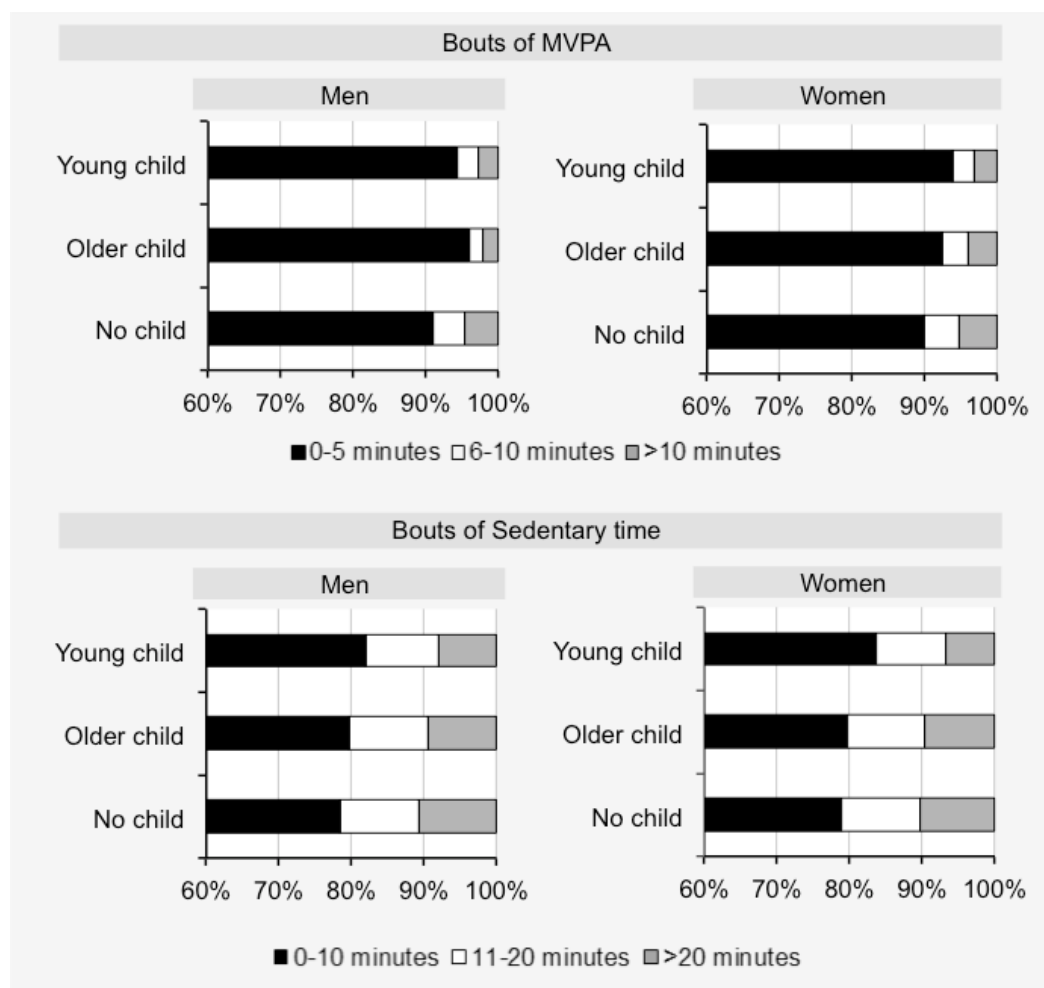
Table 13 shows the frequency and duration of MVPA bouts and the magnitude of differences between adults with and without young children. Compared with women with no children, women with young children recorded fewer MVPA bouts per period, which were of 27% shorter mean duration on work days (small effect) and 63% shorter mean duration on non-work days

**Table 13.** Differences in duration and frequency of MVPA and sedentary bouts on work days and non-work days among men and women with and without young children

	Men			Women		
	Young child (n = 73)	Older child (n = 22)	No child (n = 177)	Young child (n = 99)	Older child (n = 46)	No child (n = 189)
Duration of MVPA bouts (min)						
Work Day						
Mean ± SD	2.1 ± 0.9	1.8 ± 0.4	2.7 ± 1.1	2.2 ± 1	2.6 ± 1.3	2.8 ± 1.4
% Diff; ±99% CL		-17; ±22	25; ±27		18; ±42	27; ±25
Inference		Small↓**	Small↑**		Small↑*	Small↑**
Non-work day						
Mean ± SD	2.2 ± 0.7	1.9 ± 1	2.5 ± 1.1	1.9 ± 0.8	1.7 ± 0.9	3.0 ± 1.5
% Diff; ±99% CL		-13; ±55	12; ±37		-9; ±39	63; ±45
Inference		Small↓	Small↑		Small↓	Mod.↑**
Frequency of MVPA bouts						
Work Day						
Mean ± SD	0.7 ± 0.6	0.7 ± 0.7	0.8 ± 0.6	0.6 ± 0.4	0.6 ± 0.5	0.7 ± 0.5
% Diff; ±99% CL		-2; ±61	6; ±32		8; ±52	34; ±36
Inference		Trivial	Trivial <sup>0</sup>		Trivial	Small↑**
Non-work day						
Mean ± SD	0.6 ± 0.4	0.6 ± 0.7	0.7 ± 0.5	0.5 ± 0.4	0.5 ± 0.2	0.6 ± 0.4
% Diff; ±99% CL		1; ±97	13; ±40		3; ±50	31; ±43
Inference		Trivial	Trivial <sup>0</sup>		Trivial	Small↑**
Duration of sedentary bouts (min)						
Work Day						
Mean ± SD	13.9 ± 7.0	15.7 ± 6.7	15.7 ± 7.5	11.6 ± 5.4	15.5 ± 13.2	16.7 ± 8.6
% Diff; ±99% CL		13; ±41	13; ±23		34; ±58	45; ±27
Inference		Small↑	Small↑**		Mod.↑*	Mod.↑**
Non-work day						
Mean ± SD	13.4 ± 2.4	20.5 ± 5.2	17.8 ± 7.3	11.4 ± 5.5	16.0 ± 8.0	16.5 ± 6.0
% Diff; ±99% CL		52; ±61	33; ±30		40; ±58	45; ±31
Inference		Large↑**	Large↑**		Mod.↑**	Mod.↑**
Frequency of sedentary bouts						
Work Day						
Mean ± SD	5.6 ± 1.6	5.1 ± 1.5	5.1 ± 1.6	6.2 ± 1.6	5.0 ± 3.6	5.0 ± 1.7
% Diff; ±99% CL		-8; ±21	-8; ±11		-19; ±27	-20.2; ±8
Inference		Small↓	Small↓**		Mod.↓*	Mod.↓**
Non-work day						
Mean ± SD	5.8 ± 1.0	4.7 ± 0.4	4.9 ± 1.3	6.5 ± 1.6	5.4 ± 1.7	5.2 ± 1.2
% Diff; ±99% CL		-18; ±17	-16.5; ±10		-16; ±19	-19; ±8
Inference		Mod.↓**	Mod.↓**		Mod.↓*	Mod.↓**

Inferences are based on uncertainty in the difference in relation to the smallest important difference of 0.20 between-subject SD. Arrows indicate the direction of the difference from the group with a young child at home. Asterisks indicate inferential comparisons as follows: clear substantial difference at the \*90% and \*\*99% level, and clear trivial difference at the <sup>0</sup>90% and <sup>00</sup>99% level. All other differences are unclear. The magnitude of difference (difference in means divided by between-subject SD) was determined as follows: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate (mod.); ≥ 1.20, large.

(moderate effect). By comparison, differences between women with young children and those with older children were mostly unclear; a small clear effect was observed for the average duration of MVPA bouts on work days. Among men, clear small effects were observed for MVPA bout duration on work days, where men with young children recorded 17% longer bouts than men with older children, but 25% shorter bouts than men with no children. There were trivial differences between men with young children and no children for the frequency of MVPA bouts per period. Figure 11 shows the proportion of sporadic, short, and sustained MVPA bouts per period. Figure 11 shows the proportion of sporadic, short, and sustained MVPA bouts; both women and men with young children recorded a smaller proportion of sustained MVPA bouts ( $\geq 10$  min).



**Figure 11.** Proportion of bouts accumulated in sporadic, short, and sustained bouts of MVPA and of sedentary time.



## Patterns of sedentary time

Table 13 also shows the frequency and duration of sedentary time bouts and the magnitude of differences between adults with and without young children. Women with young children recorded the highest frequency of sedentary bouts per period; however these bouts were ~5 min shorter than women with no children on both work days and non-work days (moderate effects). Compared with women with older children, having a young child was associated with ~4 min shorter bouts on work days and ~5 min shorter on non-work days. Among men, the effects of having young children on bouts of sedentary time were more apparent on non-work days; those with young children recorded more sedentary bouts per period but of shorter average duration than those with older children (~7 min) and those with no children (~4 min). During work days, small differences were observed between men with young children and men with no children (~2 min shorter). Both women and men with young children recorded a smaller proportion of sustained sedentary bouts of long duration ( $\geq 20$  min) and a greater proportion of sporadic bouts (0–10 min) than those with older children or no children, and this is more evident among women (Figure 11).

## Discussion

This study investigated the patterns of MVPA and sedentary time in terms of bout frequency and duration, among adults with young children, adults with older children, and adults with no children. Overall, having young children in the household was cross-sectionally associated with shorter mean bout durations and with a smaller proportion of sustained bouts of both MVPA and sedentary time. These findings suggest that physical activity of adults with young children is more intermittent than those with older children or no children.

Encouragingly, findings from this study indicate that the presence of young children in the household has a clear and consistent relationship with the way in which sedentary time is accumulated in both women and men, with shorter and more frequent bouts. This intermittent pattern of sedentary time probably reflects the types of activities undertaken by parents (i.e., more childcare and household activities<sup>94</sup>), the simultaneous and enfolded nature of these activities,<sup>97</sup> and the frequent interruptions experienced by parents.<sup>165</sup> To date, no other studies have examined patterns of sedentary time among parents. Self-report estimates of sitting time

suggests parents spend less total time in sedentary time than non-parents.<sup>15,120</sup> Although evidence is emergent, a number of studies have reported cross-sectional associations between cardio-metabolic health outcomes and frequent breaks in sedentary time, independent of total sedentary time and physical activity levels.<sup>31,66,268</sup> As such, short sporadic bouts of sedentary time are considered important for health risk reduction.

On the other hand, differences in patterns of MVPA were in the opposite direction with a negative association of young children in the household on the duration and frequency of MVPA bouts, particularly among women. In general, bouts of MVPA were less frequent and shorter in duration among those with young children. Indeed, parents have reported that their participation in physical activity is regularly disrupted due to the needs of children,<sup>20</sup> and the significant constraints faced by parents for engagement in independent leisure-time physical activity are well established.<sup>17-19,128,167,169,188,189</sup> Furthermore, while a number of routine household and childcare activities require moderate-intensity exertion (3 – 6 METs),<sup>152</sup> these activities are usually not sustained for long at this intensity.<sup>80</sup>

Only one study to date has examined bouts of accelerometer-determined physical activity among parents;<sup>35</sup> their findings showed that women with young children (< 6 years) and men with older children (6–11 years) accumulated less MVPA in sustained bouts of  $\geq 10$  min than those with no children. Similar findings from the present study indicate that men and women with young children accumulate a smaller proportion of MVPA bouts in sustained bouts of  $\geq 10$  min than those without children. Currently evidence for the benefits of MVPA accumulated in shorter bouts (< 10 min) is limited and dose-response continues to be debated.<sup>269-273</sup> Official guidelines for physical activity espouse bouts of at least 10 min duration for health benefit, in addition to frequent participation in activities of daily living that are undertaken in bouts of less than 10 min duration.<sup>80</sup> However, these guidelines are based on evidence from self-reported physical activity and do not translate well to accelerometer-derived MVPA.

In this study the presence of young children in the household was associated with beneficial patterns of sedentary time and a lack of sustained bouts of MVPA. With recent developments in the field of physical activity and sedentary epidemiology, both of these distinct behaviours have important implications for health and require equal attention. The aims of this study were to understand how the presence of young children is associated with the manner in which activity

is accumulated, so that consideration may be given to how physical activity could be increased and sedentary time reduced within the constraining parameters of parenting. The health promotion message: 'sit less, move more, and exercise',<sup>81</sup> is a novel way to promote optimal human movement and may be a relevant message for parents. Given the promising patterns of sedentary time among parents in this study, reframing everyday parenting and household activities as an opportunity for moving more and sitting less may be a worthwhile approach to enhancing these patterns. On the other hand, the 'exercise' element of this message requires a targeted approach; promoting a variety of strategies to encourage MVPA through purposeful exercise and integrated family activities may be appropriate in this population. For example, low-volume high-intensity training<sup>274</sup> may be a time-efficient strategy for time poor parents.

This cross-sectional study of both males and females utilised a robust multi-stage sampling design. The URBAN study was not specifically designed to measure physical activity among parents; as such presence of children in the household was used as a proxy indicator of parenthood. It is possible that some misclassification of parent subgroup may have occurred. Strengths of this study are the inclusion of both men and women, the use of an objective measure of physical activity, and utilisation of the time-stamped nature of accelerometer data to determine patterns of physical activity and sedentary time. Sedentary time was identified using standard count thresholds and it is not possible to distinguish genuine sedentary activities (activities  $\leq 1.5$  METs in sitting or reclining posture<sup>93</sup>). Nevertheless, this accelerometer-derived measure of sedentary time provides a useful indicator of time spent in activity at the lowest end of the intensity spectrum. Similarly, MVPA was estimated using non-standard count thresholds, although there is much debate surrounding count thresholds.<sup>260</sup> The selection of different count thresholds and criteria for valid days is likely to have an effect on cross-study comparability of activity estimates. Nonetheless, these procedures were standardised in this study therefore comparisons between groups and days, and thus the associations found in this study, are unlikely to be affected.

## Conclusions

Research has shown that not only is total volume of physical activity and sedentary time important for health, but also the manner in which it is accumulated. As such, this study provides a novel analysis of physical activity and sedentary time among adults with and without

young children by examining the patterns of these behaviours. The presence of young children was associated with beneficial patterns of sedentary time in adults, through frequent short bouts. On the other hand, adults with young children engage in shorter and less frequent bouts of MVPA than adults with no children. Health promotion messages to parents should reframe everyday parenting activities as opportunity for movement.

## Chapter 8

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### Discussion

The World Health Organisation and other leading health agencies around the world recognise physical inactivity as one of the foremost risk factors for non-communicable disease and premature mortality.<sup>41</sup> Public health recommendations for physical activity have been issued and many population-wide strategies have been implemented to encourage individuals to increase their level of physical activity. But these public health messages are biased towards planned and purposeful physical activity as this is what epidemiologic measures of physical activity have traditionally captured. So far there has been little consideration of the totality of physical activity—that which is accumulated at various intensities through daily living as well as purposeful and sustained efforts in leisure time.

A broader investigation of physical activity in adults with young children is useful because this is a life stage where habitual physical activity is likely to be missed by current methodologies and public health guidelines. Research indicates that parents of young children are a population group that may face the biggest time constraints for participation in leisure-time physical activity, and that have unique psychosocial influences on their intentions to be active. This is reflected by low prevalence rates for leisure-time physical activity, with estimates of between 51% and 66% of mothers considered insufficiently active for health (< 150 min MVPA per week).<sup>19,120,122,135</sup> On the other hand, those with children are involved in greater amounts of activities of daily living than adults without children. The research agenda in this population continues to focus on social-cognitive approaches to negotiate behavioural mediators, but these strategies fail to consider opportunities for physical activity that may be present within the parameters of parenthood. Furthermore, these strategies based on education and self-regulation are likely to be ineffective or short-lived.<sup>275</sup> One of the key factors of parenting a young child is that physical activity routines are hard to maintain as children's needs are constantly evolving, and disruptions to habits and routines are commonplace (for example, with child illness and changes to work schedules).<sup>186</sup> Alternatively, the parenting occupational environment (activities associated with parenting a young child) is present on a daily basis providing opportunities to accumulate physical activity.

More attention needs to be given to the different ways in which physical activity can be achieved, and how these activity patterns are associated with health and wellbeing. The present research provides the first step towards investigating and understanding different profiles and patterns of physical activity. This thesis draws from, and adds knowledge to, the limited body of work in physical activity in adults with young children. Overarching aims of the thesis were to investigate and critique measurement methodologies for physical activity assessment in adults with young children, and to develop a broader profile of their physical activity behaviours. A critical theme throughout this thesis was its broader application to physical activity epidemiology to better understand different ways of being physically active and what this may mean for public health messages.

## **Research summary and implications**

This body of work makes a contribution to the field of physical activity in parents and to the wider epidemiological context in several ways.

### *Measurement of physical activity in adults with young children*

One of the questions raised in Chapter 2 was whether the true amount of physical activity accumulated by adults with young children had been captured in previous studies. In order to understand this further, Chapter 3 presents a systematic review of the methods of physical activity measurement that have been employed in previous studies of women with young children. This chapter draws attention to the dominance of self-report tools that for the most part have measured leisure-based physical activity of moderate-to-vigorous intensity. At the time of this review no studies had employed accelerometers to determine the prevalence of physical activity in women with young children and evidence of sedentary behaviour was limited to one study. While the review was limited to published studies of women with young children this was due to a distinct lack of studies among men with young children. Findings from this review validated uncertainties as to whether parents were in fact less active than non-parents, or whether their physical activity behaviours were simply different from traditional leisure-based physical activity and thus not captured by previous studies. This study also outlined key measurement considerations for future research in this population. These outcomes set the research context and formed the thesis direction by establishing the need to examine the utility

of self-report measures of activity for application in parent samples and to investigate the broad spectrum of physical activity intensity across all domains in both women and men with young children.

Limitations of self-report measures of physical activity behaviour are widely acknowledged however previous studies have not considered whether their validity varies between demographics. While the IPAQ-LF provides a comprehensive assessment of physical activity in terms of activity performed in leisure, occupation, transport, and household domains, there are concerns over the recall validity of unstructured and unplanned non-leisure domains.<sup>27</sup> Chapter 4 examines the association between MVPA derived from the IPAQ-LF and concurrent accelerometer-derived MVPA in a large heterogeneous sample. Mean estimates of activity from self-report were higher than those recorded by the accelerometer, with approximately 2 to 3 hours of MVPA per day recalled across all domains. When individual responses were regressed against accelerometer records, a weak-to-moderate relationship between methods was evident. Of particular importance is that the magnitude of this association varied between women (weak association) and men (moderate association). This outcome has significant implications for any study employing self-report tools to estimate overall physical activity behaviour, but especially in samples of women. These findings introduced substantial doubt over the validity of behaviour estimates from the IPAQ-LF; as such accelerometer data was utilised in the subsequent studies.

The outcomes of Chapters 3 and 4 indicated substantial limitations to current knowledge of physical activity among adults with young children. Firstly, knowledge was limited to MVPA in leisure domains, and secondly significant doubt arose over the validity of this evidence. It became evident that much was yet to be understood of the overall amounts of physical activity behaviour among those with young children, the relationship with intensity, and the patterns of movement, both across the day and minute-to-minute bouts of accumulation. The following three studies were conceived in order to construct a complete profile of parental physical activity, and to investigate how this might compare with activity profiles of adults without children.

In Chapter 5, the first of the three profiling studies, physical activity across the full spectrum of intensity was examined to understand how adults with young children distribute their time across sedentary, light, and moderate-to-vigorous intensities. As noted in earlier chapters, previous studies of parental physical activity have focussed on MVPA and the relative contribution of activity below this threshold has been largely disregarded. Comparisons were made between activity of adults with older children and adults with no children. This study demonstrates that while overall physical activity—as indicated by total daily step counts—was similar across groups, differences were observed in the intensity at which this activity was performed. Specifically, adults with young children spent less time sedentary and in MVPA than those without children, which was offset by more time in light-intensity activity. This relationship was also evident in step counts; those with young children accumulated more light steps and fewer moderate steps than those with no children.

The second profiling study explored patterns of physical activity throughout the day by synthesising accelerometer-derived information on sedentary and light-intensity activity, MVPA, and steps accumulated below and above the moderate-intensity threshold. The novel use of multiple physical activity dimensions enabled a broad picture of the relationships between each dimension, such as the coexistence of high sedentary activity and high MVPA. Results from this study, presented in Chapter 6, indicate different profiles of physical activity engagement among adults with and without young children. In general, adults with young children offset sedentary activity and MVPA with light-intensity activity throughout most of the day; however adults without children alternated between periods of high sedentary and periods of high MVPA, and in some cases these intensities coexisted together. The hour-by-hour patterning also revealed distinct day structures for those with and without children; while women with young children began their day with high levels of light-intensity activity which continued throughout the day, those without children displayed patterns consistent with a typical 9 am to 5 pm working day. Sedentary activity was dominant throughout the evening for all groups.

The final profiling study explored bouts of sedentary activity and MVPA to understand the pattern of activity accumulation. This study identified bouts of sedentary time and MVPA from accelerometer data, and differences between adults with and without young children were



explored for the frequency and duration of these bouts. Results clearly showed that adults with young children accumulated physical activity in shorter bouts than adults without children, with shorter mean bout durations and a smaller proportion of sustained bouts. While bouts of sedentary time were shorter, they were also more frequent which indicates that periods of sedentary time are frequently interrupted. With reference to results from Chapter Five, even though bouts of sedentary time were more frequent, the overall amount of sedentary time was still lower among adults with young children than those without children. On the other hand, MVPA bouts were both shorter and less frequent, with less time in MVPA overall, among adults with young children.

Overall, Chapters 5–7 were conceived in order to construct a broad profile of parental physical activity, and to explore how this might compare with those without children. These studies were the first to investigate physical activity across all intensities in adults with young children, and the first to report objectively-measured sedentary time and light-intensity activity. Results showed that adults with young children accumulated greater amounts of physical activity at light-intensity, with less time in sedentary and moderate-to-vigorous intensities than adults without children. However, the overall amount of physical activity accumulated across all intensities was, in general, not significantly different from those without children. Exploration of patterns of physical activity showed high levels of light-intensity activity throughout the day, from 7 am until 7 pm, with physical activity accumulated mostly in short sporadic bouts. Together, these findings indicate that adults with young children achieve substantial physical activity by accumulating movement across the whole day.

The magnitudes of these relationships are important to consider in order to understand whether or not these differences are meaningful. The distinct advantage of using inferential statistics in these analyses is the ability to make inferences about the true value of effects (a difference in means), and whether these differences are trivial, small, moderate, or large in a non-clinical sense. Inferences are based on where the confidence interval lies in relation to thresholds for substantial effects; if the confidence interval overlaps substantial positive and negative values, the effect is described as being unclear, otherwise the effect is deemed clear. The magnitude of a given clear effect is determined from its observed standardised value (the difference in means divided by the between-subject standard deviation).<sup>40</sup> In general, effect sizes for clear differences were small for men, however a large effect for the difference in the duration of

sedentary bouts on non-work days (~4 min), and a moderate effect for the difference in the proportion of non-work hours spent in MVPA (~3 min), were observed between men with young children and men with no children. These results indicate that greater differences in physical activity occur outside of work hours for men. Among women, effect sizes were generally larger but similarly, the largest effect sizes were observed for non-work periods; large effects were observed for the proportion of time spent in MVPA (~15 min) and moderate steps accumulated (~1,900 steps) on non-work days, and for the proportion of non-work hours spent in MVPA (~6 min). Effect sizes for differences in sedentary time were generally small, except for the duration of sedentary bouts on work days and non-work days which were moderate (~5 min). Differences in light-intensity activity were moderate on work days (~60 min), but small on non-work days (~40 min).

These standardised effects provide a useful starting place for determining meaningful differences in physical activity, however understanding of whether these differences correspond with meaningful differences in health outcomes is unclear. The majority of evidence for the association between physical activity, sedentariness, and health outcomes is epidemiological which means that precise dose-response relationships are not clear. Physiologically, responses to exercise and prolonged periods of sedentariness are different and thus influence health via different mechanisms,<sup>71</sup> and we are only just starting to understand these differences. However, what constitutes a healthy dose of sedentary time, light-intensity, or MVPA is also likely to be highly individual, and complex interactions of bout durations, bout frequencies, and overall accumulated time in each of these intensities are likely to have different outcomes for health.

Some differences were also observed between those with young children and those with older children. While there were trivial differences in the total accumulation of physical activity for women, there were differences in the way this was accumulated. In general, women with older children were more sedentary, but accumulated more MVPA than women with young children. Bouts of sedentary time were also longer and less frequent among those women with older children. Differences between men with young children and those with older children were mainly unclear; the lack of clear findings indicate that more data is needed to detect any effect. The sample size of men with older children was low ( $n = 22$ ) because of analysis of the low age tertile only. Results from the mid age tertile (shown in Appendix E) show that differences are

present in sedentary time and light-intensity activity on non-work days, and MVPA on both work days and non-work days. More understanding is needed of how physical activity tracks throughout parenthood and how factors such as the increasing age of the youngest child influences adults physical activity behaviour.

#### *Physical activity profiling with accelerometer data*

Accelerometer data offer an array of possibilities for investigation; one area that has been underutilised is the ability to synthesise activity data accumulated at multiple intensities to provide more meaningful inferences about behaviour. For example, periods of co-occurring high light-intensity activity and low sedentary time may be indicative of movement through activities of daily living. Furthermore, the nature of time-stamped data provides an ideal opportunity for analysis of within-day patterns as well as between-day patterns. One of the challenges of having such complex data is that multiple decisions have to be made with regards to treating the data and the subsequent analysis which contributes to the variability of reports in the literature. The novel approaches applied in this body of work related to both the treatment of accelerometer data for analysis, and the subsequent interpretation of analysis.

Firstly, each 60 s epoch was classified as sedentary, light, or moderate-to-vigorous intensity, and these data were then reduced to hourly summaries. This enabled the wear time criteria to be relaxed minimising data loss from application of a stringent (and often unrealistic) wear-per-day criteria. This also provided consistent daily estimates based on an average per hour, rather than daily estimates from varying wear-time contributions. Another feature of the data treatment procedures and mixed modelling approaches, was that the true-between subject variation was determined. Individuals vary their physical activity from hour-to-hour, and from day-to-day, contributing to within-subject variation. What is more important, however, is the true variation between individuals. The random effects in the mixed models took into account this repeated measurement by interacting the identity of the participant with the identity of the hour, the identity of the day, and the residual. Thus, this approach to analysis enabled the true variation between individuals to be examined.

Secondly, a variety of analyses were undertaken to understand a broad profile of physical activity in adults with and without young children. This included overall amounts of activity at

various intensities on work days and non-work days and during work hours and non-work hours, the number of steps accumulated, hour-by-hour patterns, and patterns of activity bouts. Physical activity is a complex multi-dimensional behaviour which can be thought of in terms of its dimensions – the frequency, intensity, duration, and type of behaviour. Understanding how these dimensions interrelate can provide deeper insights into what type of activity and how much activity is beneficial for health. Chapter Six investigated the totality of physical activity by examining the interplay between time spent in sedentary, light, and moderate-to-vigorous intensities, with reference also to the number of steps accumulated in each period. Simultaneously taking into account multiple variables from accelerometer data provides a broader picture of the overall behaviour than single dimensions alone, and acknowledges the complex nature of physical activity. While it is not possible to determine the actual type of activity or the context of activity, synthesis of these data provide a simple representation of the activity level occurring during each period and deeper insight into the way in which physical activity occurs throughout the day. This body of work provides a novel contribution to knowledge of physical activity in parents, in terms of a broader and more complete profile, but it also makes a significant contribution to knowledge of accelerometer profiling of physical activity.

#### *Contributions to physical activity epidemiology*

An important theme throughout this thesis is its broader application to physical activity epidemiology to better understand different ways of being physically active and what this may mean for public health messages. The approaches employed in this study highlight some distinct differences in the way physical activity may be performed. Highlighted in particular by the hour-by-hour activity profiles in Chapter Six, adults with young children tended to accumulate physical activity at lower intensities throughout the day, with periods of high sedentary time occurring only during the evenings. On the other hand, adults without children presented distinct periods of high sedentary time offset with periods of high MVPA, and some periods where high levels of these behaviours coexisted together.

From an evolutionary perspective these profiles may be important; hunter-gatherer movement patterns were likely to consist of low-level movement accumulated throughout most of the day, with the occasional brief period of very hard, high-intensity activity.<sup>276</sup> However, modern lifestyles are increasingly sedentary and environments offer little opportunity for continual low-

level movement, and tend to consist of prolonged sedentary behaviour interrupted by episodic light-intensity activity, or for the more active, MVPA. From this evolutionary perspective, it is highly likely that modern non-communicable diseases stem in part from the rapid changes to our movement patterns (along with other lifestyle changes) that have occurred at a faster rate than evolutionary adaptation.<sup>277,278</sup> There is evidence to show that activity at different intensities has different health benefits, however the complex interactions of activity bout durations, bout frequencies, and overall amounts of activity spent at each intensity combined with individual behavioural and genetic histories produce a highly individualised dose-response relationship with health. The concept of a non-linear hormetic dose-response function has particular relevance for understanding this individualised response. Hormesis is an adaptation to a stress or stimulus that in a large dose is toxic, but at appropriate levels is essential for brain derived neurotrophic growth factor (BDNF), low insulin, increased Insulin-like growth factor (IGF-1), and low reactive oxygen species (ROS).<sup>202,279</sup> While stress is essential for biological function, too much or too little stress leads to a maladaptive response of insulin resistance, inflammation through ROS, and sometimes, adverse levels of IGF-1. A range of lifestyle-related stimuli, such as exercise, diet, environment, stress, and sleep, along with genetics and recent history, operate concurrently via different mechanisms but achieve the same biochemistry, producing a highly individualised response.<sup>202</sup> What this means for physical activity, is that at certain levels physical activity can become toxic, and this level is highly dependent on other hormetic stress responses.<sup>280</sup> For example, a high-volume episode of MVPA on top of poor sleep, high stress, and sun over-exposure, may have this maladaptive response. In terms of the results from this study, the high levels of light-intensity activity observed in adults with young children could be supplemented with occasional very high-intensity activity, such as through polarised or high-intensity interval training (HIT), in order to achieve a beneficial hormetic stress response.

Much more work needs to be done to understand responses to different intensities and different profiles of behaviour (with varying interactions of bouts and intensities) however current public health messages may be too simple and fail to recognise the evolutionary and biological need to move. Based on this evolutionary perspective, the recommendation put forth by Tudor-Locke and Schuna<sup>81</sup> for adults to sit less, move more, and exercise may be a good starting place. Finding opportunities to move throughout the day can be a challenge for most people with predominantly chair-based occupations, sedentary leisure activities such as television viewing,

automobile transportation, and labour saving devices. Although parents in modern society are unlikely to achieve the levels of activity achieved by previous generations, it appears that opportunities are present for continuous movement.

## **Study limitations**

The series of studies conducted had the following limitations:

1. Data for the validation study were drawn from the wider URBAN study and there was a large loss of participants due to inadequate wear time (38% participant loss). A stringent wear time criteria ( $\geq 5$  days of  $\geq 10$  hours valid wear time per day) was necessary for appropriate comparison with the 7 day recall tool.
2. In Chapters 3–7 the presence of children in the household was used as a proxy indicator of parenthood. Participants were partitioned into three sub-groups based on household composition information reported during the personal interview. Participants reported the ages of all children aged  $< 18$  years residing in the same household during the seven-day accelerometer measurement period. Participants were classified using a prioritised approach as follows: those with any child aged  $< 5$  years (young child), those with any child aged 5–12 years and no child aged  $< 5$  years (older child), and those without any child aged  $< 13$  years (no child). The relationship between the adult participant and child in the household could not be determined and some misclassification of parent subgroup may have occurred.
3. Partitioning of participants into even age tertiles based on even distribution across the sample was undertaken for the wider URBAN study analysis. This provides some advantages for this body of work, but also some limitations. Firstly, analysis by age tertiles to some degree matches participants with and without young children by age, thereby limiting the effect of more older adults in the ‘no child’ group. It also minimises the effect of older parents in the ‘young child’ group, where age may be a confounding variable. On the other hand, the age range of the low age tertile does not span the child-bearing years (usually defined as 15–49 years), although it does include ages with the highest fertility rate (30–34 years, followed by 25–29 years<sup>105</sup>). Furthermore,

comparison of adults with young children with those with older children in the low age tertile is limited by the small sample size observed for adults with older children; more adults with older children are in the mid age tertile.

4. Application of thresholds to accelerometer counts to estimate time in sedentary, light and moderate-to-vigorous intensities is a contentious issue.<sup>260</sup> Chapter 4 used the cut point thresholds applied by the Actical software. More sophisticated statistical modelling was undertaken in chapters 5–7 and thus the wider URBAN study accelerometer count thresholds were applied. The threshold applied for sedentary time was that suggested by Wong et al.<sup>253</sup> of < 100 cpm. The MVPA threshold was determined by best-fit data simulations (unpublished data) using the Crouter 2 R equations,<sup>254</sup> undertaken by the resident statistician. Furthermore, intensity thresholds are based on absolute intensity (i.e., counts per minute) rather than relative intensity, which means that a classification of light-intensity may be, in relative terms, more intense for some individuals (such as those who are older or sedentary) than for others (such as those who are younger and highly active).<sup>53</sup>
5. Chapter Six used a novel approach for interpreting accelerometer data by synthesising data from all intensities. Absolute thresholds for what constitutes a high level of sedentary time, light-intensity activity, or MVPA are not available, and dependent on the thresholds applied in this study. As such, mean levels from all hourly periods (across sex and type of day) were ranked and quartile ranges calculated, with values in the upper quartile were considered ‘high’.

## **Future research**

The research into physical activity in adults with young children provided a first step in understanding a broader profile of physical activity in this population, compared with adults without young children. More work is needed to understand the factors that influence the various dimensions of physical activity in this population. It would be worthwhile to explore differences between parents who display beneficial patterns of activity (reduced sedentary time, and higher levels of light-intensity activity and MVPA) and those with higher levels of sedentary time and reduced physical activity. More understanding is also needed of how physical activity tracks

throughout parenthood. A comparison of parents at various stages in the parenting life course would be of interest, such as those with one preschool-aged child at home, more than one preschooler, a preschooler and older children, and only older children in the home.

Outcomes of this research highlight the significant opportunities that are present within everyday parenting occupations for accumulation of physical activity and reducing sedentary time. Further research would be beneficial on the perceived feasibility of increasing physical activity through integration with everyday parenting occupations and active family activities, such as at the park, bush walks, and cycle trails. To this end, investigation of how adults with young children interact with their local neighbourhood, in terms of park use, walkability, and neighbourhood destinations, would be worthwhile. Development and evaluation of an intervention in this population to increase physical activity through integration of activities, and reframing parenthood as an opportunity for physical activity, may also be of benefit. Non-work days, in particular, emerged as a time where promotion of integrated activity may be particularly useful. Integration of high-intensity interval training may be a particularly effective intervention strategy for adults with young children for a number of reasons. There is increasing evidence to support the benefit of low-volume high-intensity training for a range of health markers,<sup>281-283</sup> and it is likely to produce a more desirable hormetic response than high-volume MVPA. Furthermore, this time efficient strategy may be ideal for time-poor parents and could be integrated directly with children, or while supervising children.

From a wider perspective, more studies are needed that explore the totality of physical activity in different populations, and the subsequent associations with health. For studies employing accelerometers, the full capabilities of data derived from these monitors need to be realised. This body of work takes a step towards this by taking a whole-of-physical activity approach to analysis. Future research with accelerometers need to acknowledge the complex interactions between intensity, frequency and duration. At present, advancements in technologies and capabilities for analysis have led to more intricate understanding of physical activity behaviours and patterns that has developed at a faster rate than knowledge on the resulting health associations. In particular, much more work is needed to determine the associations between accelerometer-derived physical activity and health, as these are likely to differ from those established via self-report measures of physical activity. Furthermore, more understanding is



needed of the varying physiological responses to sedentary, light, and moderate-to-vigorous intensities, and the complexities of bout accumulation, in order to move the field beyond its reliance on epidemiological evidence.

## **Conclusion**

How much physical activity and what type(s) of physical activity are needed for optimal health and wellbeing is the most relevant challenge for physical activity epidemiology. This body of work has provided valuable information on different profiles of physical activity behaviour, in terms of different amounts at varying intensities. We now know from this research that adults with young children accumulate higher levels of light intensity throughout the day, with relatively lower levels of sedentary time and MVPA, and that activity in this population is accumulated in short bouts. This is different from the traditional profile of behaviour observed in adults without children, with distinct periods of high sedentary time and MVPA. The challenge for public health is to understand differences in patterns of living that lead to these different profiles of physical activity behaviour, and to develop relevant and targeted health promotion messages that lead to sustainable behaviour change. For this to occur a considerable amount of work is needed to determine more precise health responses from different amounts, types, and patterns of physical activity.

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## Appendices

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Study protocol

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## Understanding the Relationship between Activity and Neighbourhoods (URBAN) Study: research design and methodology

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### Abstract

**Background:** Built environment attributes are recognized as being important contributors to physical activity (PA) engagement and body size in adults and children. However, much of the existing research in this emergent public health field is hindered by methodological limitations, including: population and site homogeneity, reliance on self-report measures, aggregated measures of PA, and inadequate statistical modeling. As an integral component of multi-country collaborative research, the Understanding the Relationship between Activity and Neighbourhoods (URBAN) Study seeks to overcome these limitations by determining the strengths of association between detailed measures of the neighborhood built environment with PA levels across multiple domains and body size measures in adults and children. This article outlines the research protocol developed for the URBAN Study.

**Methods and design:** The URBAN Study is a multi-centered, stratified, cross-sectional research design, collecting data across four New Zealand cities. Within each city, 12 neighborhoods were identified and selected for investigation based on higher or lower walkability and Māori demographic attributes. Neighborhoods were selected to ensure equal representation of these characteristics. Within each selected neighborhood, 42 households are being randomly selected and an adult and child (where possible) recruited into the study. Data collection includes: objective and self-reported PA engagement, neighborhood perceptions, demographics, and body size measures. The study was designed to recruit approximately 2,000 adults and 250 children into the project. Other aspects of the study include photovoice, which is a qualitative assessment of built



environment features associated with PA engagement, an audit of the neighborhood streetscape environment, and an individualized neighborhood walkability profile centered on each participant's residential address. Multilevel modeling will be used to examine the individual-level and neighborhood-level relationships with PA engagement and body size.

**Discussion:** The URBAN Study is applying a novel scientifically robust research design to provide urgently needed epidemiological information regarding the associations between the built environment and health outcomes. The findings will contribute to a larger, international initiative in which similar neighborhood selection and PA measurement procedures are utilized across eight countries. Accordingly, this study directly addresses the international priority issues of increasing PA engagement and decreasing obesity levels.

## Background

Increasing physical activity (PA) engagement and reducing obesity levels at the population-level have been identified as national [1] and international [2,3] health priorities. Multiple factors at different levels, including personal, family, social, environmental, and economic attributes, have been shown to influence PA and obesity patterns [4]. Environmental determinants, such as changes in urbanization patterns and the built environment, increased use of labor-saving devices, greater participation in sedentary activities, and reliance on automobiles for transport are now being recognized as key contributors to these health outcomes [2,3,5]. Urban sprawl, a composite measure of many built environment elements, has also been positively related to population-level overweight/obese status [6-8], potentially through reduced accumulation of PA via increased reliance on cars and reduced access to local destinations and public transport infrastructure. Despite these emerging relationships, studies in this field often have methodological flaws that limit the robustness of the findings. More rigorous data are urgently required to inform decision-makers of the built environment variables with greatest potential for improving PA and obesity outcomes.

A number of built environment features have been consistently identified as promoting PA in both adults [9-11] and children [12,13]. For adults these include increased street network connectivity, higher residential population density, greater access to public spaces, shops, and services, and higher levels of mixed land use [14-17]. Adult PA levels are also influenced by streetscape characteristics including neighborhood aesthetics, green space, pedestrian infrastructure, and safety factors [16-20]. For children, distance to school [21], neighborhood design [13,22], traffic safety [23], and access to green spaces [24] and recreation locations [12] have been associated with PA engagement.

Although this evidence is accumulating, there are limitations in many of the studies on which it is based. To date, the majority of research investigating built environment

variables with PA engagement and body size has relied on self-report measures, largely drawn from adult samples based in the United States and Australia. Although self-report measures are practical to implement, they do not accurately detect incidental PA accumulation [25] and are affected by recall bias in adults [25] and children [26]. Also, neighborhoods have often not been selected to maximize variation in built environment attributes. Capturing neighborhood variability is fundamental to understanding the magnitude of built environment effects on individual PA engagement within these communities.

Ethnic differences in relation to built environment variables have also been understudied. Within New Zealand, Māori (New Zealand's indigenous people) have higher obesity rates when compared with New Zealand Pākehā/European [27], and it is unknown whether urban form characteristics may influence these groups differently. Furthermore, little research has been conducted with children in this context; yet given the more sporadic nature of PA engagement displayed by children when compared with adults, it is conceivable that built environment variables associated with PA and body size will differ for adults and children. Parental perceptions of neighborhood safety (e.g., stranger danger, traffic concerns) may also be an important influencing factor regarding children's PA engagement [23]. Ignoring these important variables is likely to have resulted in population and site homogeneity, which in turn, may lead to underestimation of effect sizes in associations between the built environment and health outcomes. A further limitation of existing research in this field has been the use of rudimentary analytical techniques that ignore clustering and the multilevel or hierarchical structure of data on individuals living in different households, neighborhoods, cities, and countries. Multilevel modeling that can simultaneously account for factors at individual and neighborhood levels is likely to provide a more robust and sophisticated understanding of PA and health determinants [28].

The International Physical Activity and Environment Network (IPEN) study was set up to overcome the limitations



inherent with many previous studies and to address the paucity of rigorous scientific evidence available in this field (refer <http://www.ipenproject.org>). Key strengths of the collaborative study are the: multi-country participation (Australia, Belgium, Colombia, Czech Republic, Hong Kong, New Zealand, United Kingdom, United States of America) to ensure inclusion of diverse urban environments, and the use of standardized protocols to measure the built environment (geographical information systems (GIS)), PA engagement (International Physical Activity Questionnaire – Long Form (IPAQ-LF), accelerometry), and other health outcomes (body size). Once collected, participant and neighborhood data will be combined to facilitate intra-and inter-country multi-level comparisons of built environment, PA, and health outcomes. This will produce more accurate effect size estimations, and improve understanding of international associations between the urban design, PA, and body size status. Purposefully stratifying neighborhoods based on built environment attributes and combining data from multiple sites in diverse countries will ensure that a larger variation of environmental attributes will be gained than those available from any one country.

The Understanding the Relationship Between Activity and Neighbourhood (URBAN) Study contributes to this collaboration by collecting New Zealand-specific built environment and health data from four diverse cities in accordance with IPEN protocols. In addition to the design strengths of the IPEN collaboration, the URBAN Study has incorporated several additional features that will add to its potential to contribute to understanding in this field: a child sample, stratifying neighborhoods by walkability and ethnicity, door-to-door recruitment of participants, streetscape audits, in depth assessments of the perceived environment (via photovoice), and individualized walkability profiles based on participants' residential location. This paper outlines the methods developed for use in the URBAN Study.

## Methods

### Study aim

The overarching aim of the URBAN Study is to understand the associations between neighborhood built environment variables, PA engagement, and body size. Measures of neighborhood urban design, PA levels across multiple domains (leisure, transport, habitual, and overall), and body size will be used to model the associations and establish effect sizes in a diverse sample using apposite statistical modeling.

### Study design

This research is a cross-sectional study that examines the associations between neighborhood urban design, PA levels, and body size in adults and children residing in

selected neighborhoods within four cities in New Zealand (North Shore, Waitakere, Wellington, and Christchurch). The sites were selected for their geographical diversity and because of existing access to city-level GIS data. The study was conceptualized using a multilevel framework, with the levels being: country, city, neighborhood, household, and individual. The URBAN Study is being conducted in seven phases, where each phase informs the subsequent stages of the research (Figure 1). Recruitment for the URBAN Study commenced in April 2008 in North Shore City, and the project uses a rolling data collection process across the four cities; it is anticipated that it will take one and a half years to complete the door-to-door data collection component of the study (phase 4). The host institutions of the research granted ethical approval for the outlined study procedures (AUTC: 07/126, MUHECN: 07/045).

### Phase 1: Neighborhood stratification

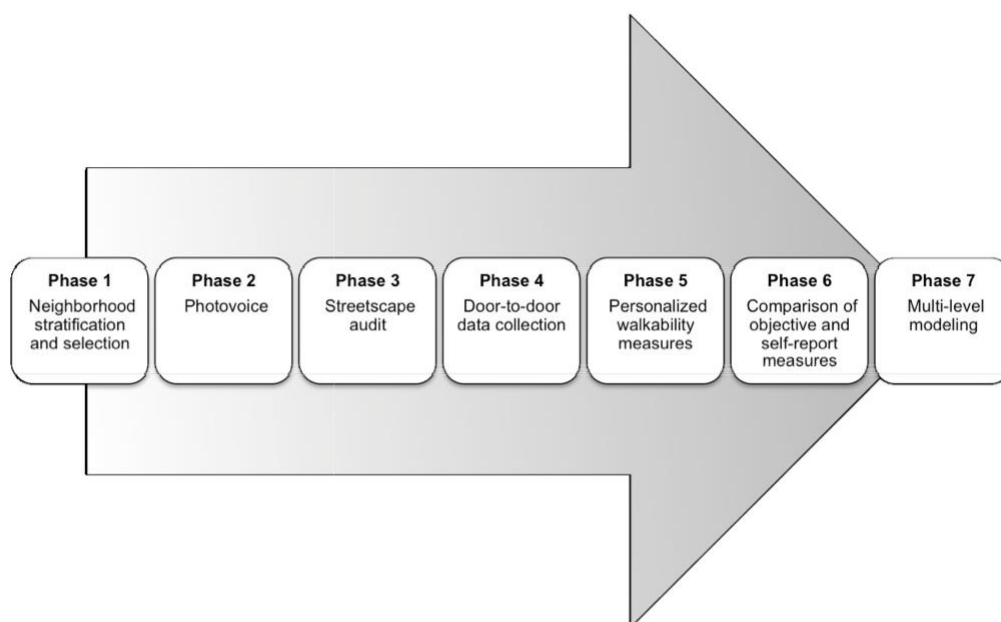
Within each of the four cities, 12 neighborhoods were selected for investigation. In order to select neighborhoods, a walkability index was created and the domiciled Māori population was estimated. These values were applied to each mesh-block within the cities' boundaries. A mesh-block is a geographic census unit of approximately 100 households constructed by Statistics New Zealand [29]. The walkability index was calculated using combined measures of street connectivity, dwelling density, land use mix, and retail floor area ratio, and was generated using GIS software, ArcInfo 9.1 (ESRI, Redlands, CA). The construction of these measures replicates existing IPEN research procedures [10,30]. Each of the walkability variables is discussed below.

#### • Street connectivity

Street connectivity was estimated by calculating intersection density. Street intersections with three or more unique intersecting streets were extracted from road network data. Mesh-block boundaries are typically defined by street centerlines. Therefore, to ensure that street intersections coincidental with mesh-block boundaries were included, intersection density was calculated as the number of intersections per square kilometer within 20 meters of each mesh-block boundary. Values for each mesh-block were between 0 and 1, where a score closer to 1 indicated higher street connectivity.

#### • Dwelling density

The number of dwellings was estimated using mesh-block data for the number of occupied private dwellings taken from the New Zealand 2006 census [29]. Residential land area was obtained from the land use and zoning data provided by the territorial authorities. Dwelling density was calculated by dividing the number of dwellings by the residential land area for each mesh-block.



**Figure 1**  
Diagram of the overall research design for the URBAN Study.

• *Mixed land use*

The land use and zoning data were used to categorize land uses into commercial, residential, industrial, open space, and other within each mesh-block. The land use mix was calculated using an entropy index [31], where 0 indicates homogeneity of land use, and a value closer to 1 specified greater heterogeneity of land uses.

• *Retail floor area ratio*

The retail floor area was determined by using building outline data sourced from the territorial authorities. The net retail area was then calculated by dividing the retail floor area by the total retail parcel area within each mesh-block [10]. A higher value indicated less parcel space allocated to car parking at retail sites within the mesh-block.

• *Walkability index*

The walkability index was calculated separately for each city using the above four measures (street connectivity, dwelling density, mixed land use, and retail floor area ratio). The measures were classified into deciles and recoded into values from 1 (1<sup>st</sup> decile) to 10 (10<sup>th</sup> decile). The walkability index for each mesh-block was calculated by summing the four 1 to 10 scores, resulting in a possible score from 4 to 40.

• *Māori population*

Distribution of usual Māori residents domiciled within each mesh-block within the four cities was estimated by using 2006 census data [29]. Following the walkability index procedures, the mesh-block Māori population density was classified into deciles and recoded into values from 1 (1<sup>st</sup> decile) to 10 (10<sup>th</sup> decile) for each city. Māori comprise 14.6% of the resident population. They are the second-largest ethnic group (after New Zealand Pākehā/European) in New Zealand [32].

• *Neighborhood selection*

Within each city, walkability and Māori population density were each partitioned into tertiles (lower (deciles 1–3), middle (deciles 4–7), and higher (deciles 8–10)). In the interest of capturing variability, only mesh-blocks with higher walkability and higher Māori population density, higher walkability and lower Māori population density, lower walkability and higher Māori population density, and lower walkability and lower Māori population density were eligible for this study. The middle tertile was removed from further analysis at this point.

All eligible mesh-blocks were then identified on city maps and clusters of five contiguous mesh-blocks of similar



walkability and/or Māori population density characteristics were grouped together to form neighborhoods. The research team then purposefully selected three neighborhoods for each walkability/Māori population strata per city. This ensured geographical spread within each region and diversity across cities were captured. In total, 12 neighborhoods were selected per city and 48 neighborhoods were chosen across New Zealand. All neighborhoods are drawn from urban settings. In the instances where the number of potential respondents is exhausted within the neighborhood during the door-to-door recruitment phase (generally because of a high number of commercial premises within that setting), an additional contiguous mesh-block of similar built environment and Māori population characteristics is added to the neighborhood.

#### *Phase 2: Photovoice*

Photovoice is a research method that allows individuals, including those who may be marginalized, to conceptualize their environment through photography. In this study, neighborhood features associated with PA engagement across different cities, settings, and populations are qualitatively captured by photovoice. Children, as well as adults (approximately  $n = 10$  per group) are drawn from five diverse neighborhoods in North Shore and Waitakere cities and invited to participate in the photovoice component of the URBAN Study. These participants do not necessarily partake in the door-to-door data collection aspect of the study. After an initial briefing, participants are each provided with a disposable camera to take photographs of features in their local environment they perceive make their self-defined neighborhood more and less conducive for engaging in PA. The photographs are developed, brought to a participant focus group (either adult- or child-specific). Participants presented noteworthy photos in relation to neighborhood PA attributes and explained the images to the group, both verbally and by way of captions written underneath the pictures. This process, either in small breakout groups or as a whole group discussion, enables the identification of key PA themes of significance and concern for participants in each locality. The discussions are audio taped, transcribed, and thematic induction analyses is conducted using Nvivo software (QSR, VIC, Australia). The photovoice procedures follow an established methodology [33,34].

#### *Phase 3: Streetscape audit*

In 12 selected street segments in each study neighborhood a streetscape audit using a modified version of the Systematic Pedestrian and Cycling Environment Scan (SPACES) tool [35] is undertaken to assess the presence and absence of features that support walking and cycling (e.g., physical infrastructure, aesthetics, traffic safety attributes). The SPACES, developed in Australia, has demonstrated appropriate

reliability for most variables examined in that setting ( $\kappa \geq 75\%$  agreement) [36], and was adapted for the New Zealand context. The starting point for the audit is randomly selected within the neighborhood and thereafter the street segments are selected sequentially. Scores from each street segment are combined to provide a neighborhood streetscape value. All streetscape audits are conducted when door-to-door data collection is occurring in the city. For reliability purposes, 10% of the street segments are re-audited by a second trained assessor. A training manual based on the SPACES protocols was developed for the URBAN Study that included New Zealand specific reference images.

#### *Phase 4: Participant recruitment and data collection*

Trained interviewers recruited participants using a door-to-door recruitment strategy. For each selected neighborhood, GIS is used to generate street maps, identify parcel lots, random start points, walk paths, and enumerate households. These maps are provided to three or four trained interviewers for door-to-door recruitment with instructions to approach every  $n^{\text{th}}$  household. The household sampling rate is determined by dividing the neighborhood dwelling density [29] by the estimated response rate of 60%. This value varies between neighborhoods because of the changeable number of residential dwellings located within each mesh-block. Commercial or temporary residential (e.g., motel rooms) premises are excluded from the sampling frame.

Interviewers start from GIS-derived randomly selected start points and approach the households identified by the enumeration process. The interviewers follow the predetermined walk path for each neighborhood. Forty-two households are selected in each neighborhood, and one adult and one child (where possible) are surveyed per household. This sampling strategy is designed to yield a total of 2,000 adult participants once data collection is complete. It is estimated that 250 children will be recruited into the study.

Individuals aged between 20–65 years and 3–12 years inclusive usually resident in private dwellings in the 48 selected neighborhoods are eligible to participate in the study. Where there is more than one eligible person in the household, potential participants are identified by the criterion of having the next birthday. Exclusion criteria are: falling outside the age ranges, not intending on living in the household over the measurement period, not resident in the dwelling three months prior to recruitment, unable to speak the English language, or having walking mobility restrictions, such as using crutches. The eligible child in the household is unable to participate in the research if the eligible adult from the household refuses to take part in the study. In the event that there is no eligible adult

residing in the household or the eligible adult refuses to participate, the household becomes 'closed' and the interviewer moves on to the next household identified on the neighborhood walk. If no one is at home or an eligible adult resides in the household, but is not available, the interviewer makes a maximum of five return visits for recruitment purposes. The outcome for each visit is recorded on a door-to-door call sheet. Information regarding door-to-door recruitment procedures is documented in a training manual and briefing session.

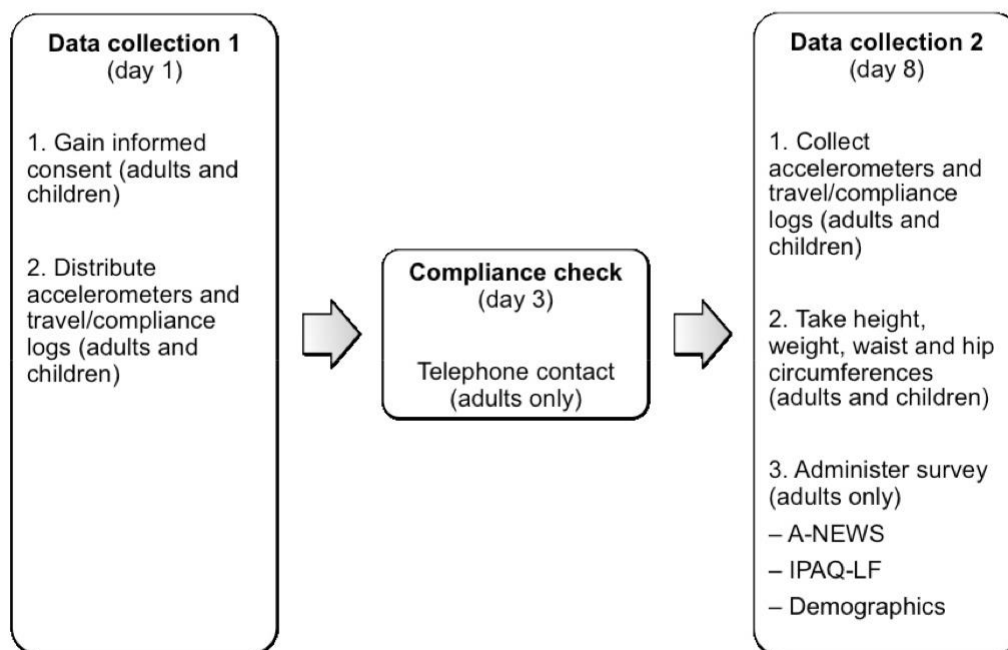
Once participants are recruited, two data collection points (data collection 1, data collection 2) are arranged eight days apart, providing a seven-day measurement period (Figure 2). At data collection 1 the interviewer introduces the study, gains informed consent/assent, and distributes the accelerometer and travel/compliance log. Data collection 1 is frequently undertaken at the point of participant recruitment. The interviewer telephones the adult participants three days after data collection 1 to monitor accelerometer compliance. At data collection 2, the interviewer collects the accelerometer and travel/compliance log, measures participants' height, weight, waist and hip cir-

cumferences, and conducts the survey with the adult participant. The interviewer follows the same call back recruitment procedures if the participant is not home for data collection 2.

The interviewer enters all information directly on to a personal digital assistant at both time points and subsequently exports the data into Microsoft Excel (Microsoft Corp, Redmond, WA) at the research centre. Quality control audits are conducted on 10% of all interviews by the fieldwork supervisor.

• *Objective PA measures*

PA is measured objectively in adults and children for seven consecutive days using hip-mounted Actical accelerometers (Mini-Mitter, Sunriver, OR) fitted to a purpose-built elastic waistband. The units have been shown to be reliable and valid for these populations [37-39]. Prior to distribution, the accelerometer supervisor prepares the units, including date stamping the devices and setting up the units to record PA and step counts in 30-second epochs. Accelerometers are distributed at data collection 1 by the interviewer and participants are instructed to wear



**Figure 2**  
Measurement battery for the door-to-door component of the URBAN Study.



the units for all waking hours for one week (seven days), but remove the monitors when participating in water-based activities. Accelerometers are collected as close as possible to eight days later at data collection 2 by the interviewer. Accelerometers are returned to the research centre and the data are downloaded into Microsoft Excel by the accelerometer supervisor. Once cleaned, data from the unit are included for further analyses if at least 10 hours of data are gathered per day, for a minimum of 5 days. This is in accordance with IPEN protocols [40]. A manual has been developed regarding accelerometer downloading and uploading procedures, data storage, and data cleaning treatment protocols, and automated data extraction procedures are currently being developed. For most analyses, the outcome variables for adults and children will be the percentage of waking time spent in sedentary, light, moderate, and vigorous PA [41].

- *Travel/compliance log*

Participants self-complete a travel and compliance log for the duration of the accelerometer data collection. Each day, participants record what transport mode(s) they use to travel to and from work or study, the times they get up and go to bed, whether the accelerometer is removed for portions of the day, and if so, what activities the participant engages in during those times. No reliability or validity testing has been conducted with this tool. The information on waking hours and accelerometer removal derived from the log are checked and matched against accelerometer data.

- *Body size measures*

The interviewer measures body size at data collection 2. Height is assessed to the nearest 0.1 cm using a stadiometer (Mentone Educational Centre, Victoria, Australia) and weight to the nearest 0.1 kg using calibrated Seca 770 scales (Protec Solutions Ltd, Wellington, NZ). Body mass index (BMI) status for adults will be determined using the World Health Organization ethnic-specific thresholds [42,43] and the International Obesity Task Force criteria [44] will be applied to children. Waist circumference is measured as the minimum value between the iliac crest and the lateral costal margin (the mid-point between the hip and the lowest rib) to the nearest 0.1 cm using a Lufkin W606PM tape (Cooper Tools, Apex, NC, USA). Hip circumference is measured at the widest part of the buttocks [45]. Age-specific thresholds for high trunk mass will be applied to the sample [46-48].

- *Neighborhood perceptions*

Neighborhood perceptions are assessed using the Abbreviated-Neighborhood Walkability Scale (A-NEWS). The A-NEWS is a 54-item tool that measures adults' perceptions of dwelling density, land use mix, street connectivity, walking and cycling infrastructure, safety, and access

to public and private facilities within their self-defined neighborhood. Responses are rated either on a four- or five-point Likert scales. Acceptable reliability and validity of the A-NEWS has been determined previously [49]. Neighborhood self-selection preferences are assessed on a five-point Likert scale using six items taken from the Strategies for Metropolitan Atlanta's Regional Transportation and Air Quality Study [50]. The neighborhood self-selection measures have also been used in the Neighborhood Quality of Life Study [51] and the Physical Activity in Localities and Community Environments [9]; these studies also contribute to the IPEN dataset.

- *Self-reported PA*

The IPAQ-LF is administered to capture adults' self-reported PA levels for the previous seven days (the period when the accelerometer was worn). The IPAQ-LF has shown to be a reliable and valid measure of PA engagement in 12 countries [40], and is used to assess PA engagement across four domains: occupational, transportation, household, and leisure. The outcome measures for overall and domain-specific PA will be frequency (days), duration (minutes), and intensity (light, moderate, and vigorous) of engagement. Self-reported PA levels will be compared with national PA recommendations, accelerometer data, and other countries participating in IPEN.

- *Demographics*

As part of the study, adult participants complete a demographic survey that examines: ethnicity, marital status, household income, academic qualifications, occupation, travel mode engagement, dwelling type, number of children living in the dwelling, time spent watching television, perceptions of body size, and the location of proximal and usually accessed food stores. Adult participants also complete the child's survey by proxy if an eligible child within the household participated in the study. Questions relating to the child include: ethnicity, screen time (e.g., television, computer, games consoles) access and rules, PA participation and motor skill ability, perceptions of body size, and access to and use of potential PA settings.

- *Weather*

Daily weather data (minimum and maximum temperature (°C), rainfall (mm)) are recorded at sites located in each of the four cities. The New Zealand Metrological Service collects and provides this information. Time-matched weather variables will be created to examine or control for the weather effects on PA engagement.

*Phase 5: Personalized walkability measures*

Personalized walkability index values will be calculated and constructed for adults and children based on the physical environment surrounding each participant's



place of residence. The buffer distance will be developed along a one-kilometer street network from the participant's residence, excluding areas that cannot be accessed due to major barriers (e.g., freeways, water features). Similar GIS approaches as used to construct the walkability indices applied to the neighborhood selection process will be used to create the personalized walkability index classifications. Other potential inclusions in the index include public open space, public transport infrastructure, and topography variables within the buffer zone. Creation of these individualized measures has been conducted in previous research [52-54], and is a useful tool to enable the objectively measured built environment variables to be compared with individual-level health and self-report data.

#### *Phase 6: Comparison of objective and self-report measures*

International research suggests there is a mismatch between measures of perceived and objectively assessed PA facility availability [55] and behaviors [56], and these relationships require further investigation. Accordingly, it is important to examine the independent associations and levels of agreement between actual and perceived PA infrastructure at the neighborhood level within the New Zealand context, and the relationships between objective and perceived PA behaviors. Objective measures derived from GIS, the streetscape audit, accelerometers, and body size will be compared with self-report measures drawn from the photovoice and door-to-door data collection components of the study.

#### *Phase 7: Multilevel modeling*

Multilevel modeling is one of the more appropriate methods for understanding how multiple factors occurring at various hierarchical levels (such as individual, household, neighborhood, and city variables) operate to influence PA engagement and body size. The sampling frame and research design enables multilevel analyses of neighborhood environmental predictors for self-reported and objectively measured PA and body size for Māori and non-Māori adults and children. These analytic strategies appropriately accommodate and model the hierarchy and clusters within the research design, and allow for the adjustment of important potential confounders (such as rainfall). Further analyses will likely consider how the influence of parental variables impacts on child health behaviors at the household level.

#### *Power calculations*

Precise power calculations depend on focused and pre-determined statistical quantities; something that can be difficult for multi-aimed and broad studies such as this. For the purpose of this study, we intend recruiting 2,000 adults. However, a 10% reduction of our data is expected due to lack of compliance, reducing the data available for

full analysis to 1,800 adults. Based on 12 background covariates explaining 25% of the variability of the dependent variable, and intraclass correlation coefficient cluster effects of 0.05, a realized sample of 1,800 adults,  $\alpha = 0.05$  and statistical power of 80%, the clustered multi-linear regression models will detect the smallest change in  $r^2$  of  $\leq 2.3\%$  and clustered logistic regression models odds ratio of  $\leq 1.27$  if the prevalence rate of overweight/obesity is 60%. For the Māori and non-Māori comparisons, we expect lower Māori neighborhoods to have approximately 7% of the usual residents classified as Māori and higher Māori neighborhoods to have approximately 30% of the usual residents to identify as Māori [32]. Assuming a significant level of  $\alpha = 0.05$  and statistical power of 80%, then the detectable difference between any Māori and non-Māori proportion is within  $\pm 10\%$  for this sample size. A difference of  $\pm 10\%$  was considered epidemiologically worthwhile and important to detect.

## **Discussion**

Although characteristics of the built environment have been related to PA engagement [9,11,12,22] and obesity levels [6-8], the epidemiological understanding of the associations between urban form and health outcomes still remains largely unknown. Improved understanding of built environmental influences on health behaviors, through socio-ecological models, is needed to inform more effective and sustainable interventions [28]. The URBAN Study will contribute to the evidence base pertaining to PA engagement, body size, and the built environment for adults and children by overcoming some of the existing methodological limitations in this field.

#### *Applications of the URBAN Study*

Four key research gaps in this area have been identified which the URBAN Study attempts to address. First, it is feasible that the limited environmental variability shown in urban locations previously investigated has underestimated the strength of associations between health outcomes and urban design [28]. The URBAN Study purposefully selects neighborhoods based on a diverse range of walkability and ethnicity characteristics, and contributes data to a multi-country study (IPEN). Second, although several studies have documented associations between the built environment and weight status [6,8] and PA engagement [57,58], confirmatory studies have yet to be conducted in diverse communities using robust measures to determine any walkability effect. Understanding these relationships in greater detail using standardized objective measurement procedures and protocols (GIS, accelerometers, body size) will provide more rigorous urban planning guidance to decision makers, thereby increasing the likelihood of improving population-level body size and PA outcomes. To our knowledge, this is the first New Zealand study to simultaneously use objective



and self-report measurement tools to assess adult and child PA levels and body size status with the built environment. Third, limited evidence exists regarding how those individuals of different ethnicities, ages, genders, and/or family structures are influenced by the impact of neighborhood design with regard to health outcomes [28]. The URBAN Study has been designed to in part address this issue, with findings that can be stratified and analyzed according to these variables. Fourth, internationally there is very little evidence available identifying which built environment variables influence children's PA and body size, and how the built environment impacts on parental choices regarding children's PA opportunities. Accordingly, the URBAN Study will contribute directly to this evidence base by examining the interactions between children's PA behaviors, body size, parental perceptions, and built environment characteristics across diverse settings and child age ranges. It is anticipated that full results of the study will be available in 2011.

#### **Strengths and weaknesses of the URBAN Study**

The obvious strengths of the URBAN Study are the: replication of international procedures and measures, neighborhood stratification and selection processes, use of objective and self-report measures, assessment of PA engagement over multiple domains, ability to control for seasonal effects, large sample size recruited, and incorporation of adults and children of diverse ethnicities into the sampling frame. Limitations of the study include its cross-sectional research design that means causality cannot be determined, and that neighborhoods are only drawn from urban settings; therefore findings cannot be applied to rural or small town environments within New Zealand. Neighborhood walkability and ethnicity classifications may also differ by region, and communities classified as being higher walkable or higher Māori population in one city may not reach the inclusion threshold for another city. However, this may also be considered a strength of the study as the design will allow any city-specific or dose-response effects to be captured, and assist with the understanding of the relative importance of other covariates and confounders. Lastly, neighborhoods are grouped according to geographic layout through contiguous mesh-blocks, rather than according to natural and social boundaries. This may create a mismatch between the GIS-assessed neighborhood and respondents' perceptions of their neighborhoods.

#### **Conclusion**

Taken together, the URBAN Study will generate robust scientific evidence by using appropriate and standardized measures to provide a New Zealand-specific understanding of the associations between urban design and health outcomes, as well as contributing data to an international research project. Providing this information will impart

urgently needed epidemiological information regarding the associations between the built environment and health outcomes. Accordingly, this study directly addresses the international priority issues of increasing PA engagement and decreasing obesity levels at the population-level.

#### **Abbreviations**

A-NEWS: Abbreviated – Neighborhood Environment Walkability Scale; BMI: Body mass index; °C: Degrees Celsius; GIS: Geographical information systems; IPAQ-LF: International Physical Activity Questionnaire – Long Form; IPEN: International Physical Activity and Environment Network; mm: Millimeters; PA: Physical activity; SPACES: Systematic Pedestrian and Cycling Environment Scan; URBAN: Understanding the Relationships between Activity and Neighbourhoods.

#### **Competing interests**

The authors declare that they have no competing interests.

#### **Authors' contributions**

HMB developed the first draft of the manuscript. HMB, GMS, KW, PJS, SM, and RK contributed to the conception and the design of the study. All authors provided critical feedback during manuscript development. Each author has read and approved the final manuscript.

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## MEMORANDUM

### Auckland University of Technology Ethics Committee (AUTC)

To: Grant Schofield  
From: **Madeline Banda** Executive Secretary, AUTC  
Date: 21 September 2007  
Subject: Ethics Application Number 07/126 **Built environments, physical activity and obesity: a national and international study (BEPAS).**

Dear Grant

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTC) at their meeting on 13 August 2007 and that as the Executive Secretary of AUTC I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTC's meeting on 8 October 2007.

Your ethics application is approved for a period of three years until 21 September 2010.

I advise that as part of the ethics approval process, you are required to submit to AUTC the following:

- A brief annual progress report indicating compliance with the ethical approval given using form EA2, which is available online through <http://www.aut.ac.nz/about/ethics>, including when necessary a request for extension of the approval one month prior to its expiry on 21 September 2010;
- A brief report on the status of the project using form EA3, which is available online through <http://www.aut.ac.nz/about/ethics>. This report is to be submitted either when the approval expires on 21 September 2010 or on completion of the project, whichever comes sooner;

It is also a condition of approval that AUTC is notified of any adverse events or if the research does not commence and that AUTC approval is sought for any alteration to the research, including any alteration of or addition to the participant documents involved.

You are reminded that, as applicant, you are responsible for ensuring that any research undertaken under this approval is carried out within the parameters approved for your application. Any change to the research outside the parameters of this approval must be submitted to AUTC for approval before that change is implemented.

Please note that AUTC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this. Also, should your research be undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply within that jurisdiction.

To enable us to provide you with efficient service, we ask that you use the application number and study title in all written and verbal correspondence with us. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at [charles.grinter@aut.ac.nz](mailto:charles.grinter@aut.ac.nz) or by telephone on 921 9999 at extension 8860.

On behalf of the Committee and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Madeline Banda  
Executive Secretary  
Auckland University of Technology Ethics Committee

From the desk of ...  
Madeline Banda  
Executive Secretary  
AUTC

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New Zealand  
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page 1 of 1

**Appendix C** MUHECN approval for the URBAN study



**Massey University**  
AUCKLAND

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(AUCKLAND & INTERNATIONAL)  
Private Bag 102 904  
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[www.massey.ac.nz](http://www.massey.ac.nz)

4 September 2007

Associate-Professor Karen Witten  
Whariki/SHORE Research Centre  
Centre for Social & Health Outcomes Research & Evaluation  
P O Box 6137  
Wellesley Street  
AUCKLAND

Dear Karen

**HUMAN ETHICS APPROVAL APPLICATION – MUHECN 07/045**  
**"Built environments, physical activity and obesity: a national and international study"**

Thank you for your application. It has been fully considered, and approved by the Massey University Human Ethics Committee: Northern.

Approval is for three years. If this project has not been completed within three years from the date of this letter, a reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

A handwritten signature in cursive script, reading "Ann Dupuis".

Associate-Professor Ann Dupuis  
Chair  
Human Ethics Committee: Northern

**Appendix D** Demographic-specific figures of association between self-report and accelerometer derived physical activity

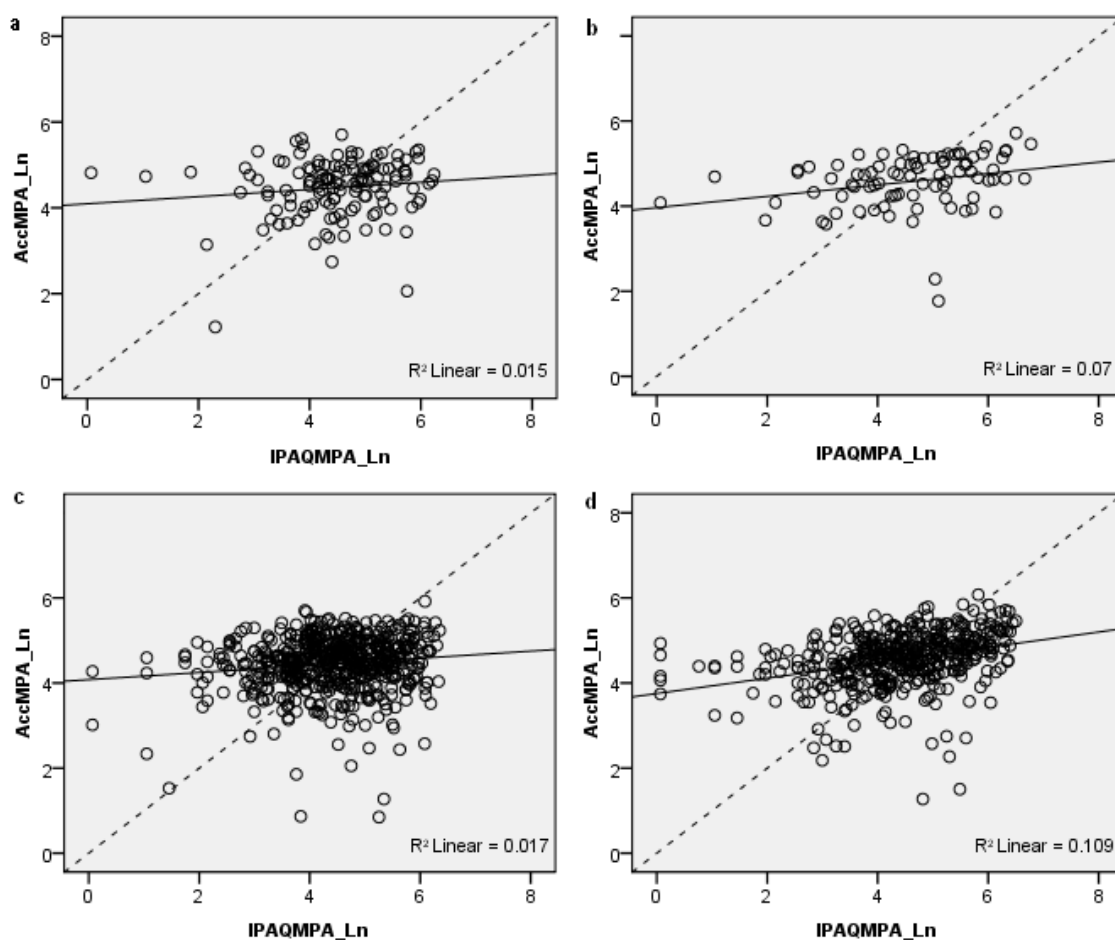


Figure D1 Association between self-report and accelerometer derived MPA for a) WYC, b) MYC, c) WNYC, and d) MNYC. Note. Dashed line represents line of identity; solid line represents linear regression line.

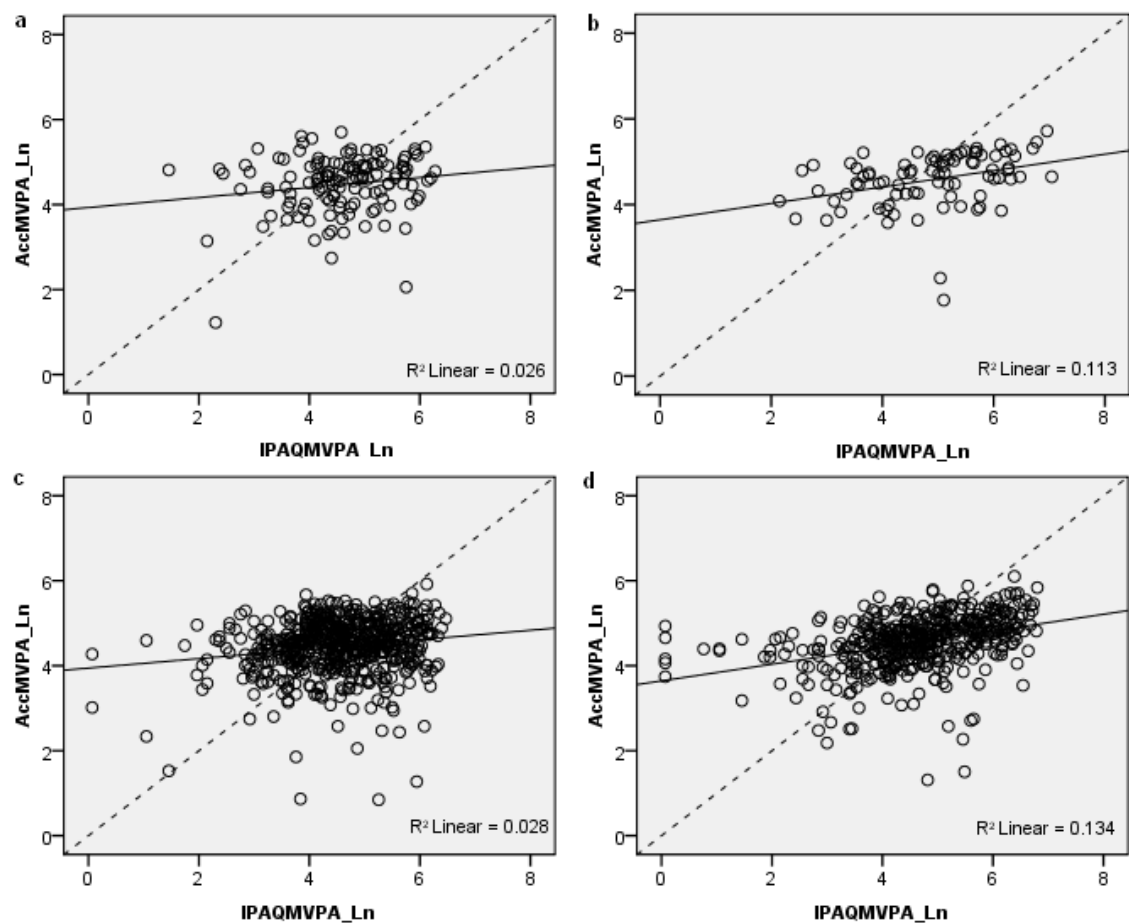


Figure D2 Association between self-report and accelerometer derived MVPA for a) WYC, b) MYC, c) WNYC, and d) MNYC. Note. Dashed line represents line of identity; solid line represents linear regression line.

## Appendix E Supplementary tables for mid and high age tertiles

**Table E1.** Characteristics of the participants in the mid age tertile sorted by men and women with and without children at home.

	Men			Women		
	Young child (n = 54)	Older child (n = 97)	No child (n = 87)	Young child (n = 95)	Older child (n = 180)	No child (n = 92)
Age (y)	45 ± 3	47 ± 3	45 ± 4	44 ± 3	47 ± 3	45 ± 4
Ethnicity (%)						
Maori/Pacific	6	11	21	23	17	14
Asian	19	22	10	9	12	13
European	76	67	69	67	71	73
Bachelor degree (%)	50	51	41	40	37	43
Income per adult (\$000)	41 ± 18	42 ± 19	45 ± 27	36 ± 16	41 ± 21	44 ± 28
Work Status (%)						
Paid work	89	92	83	55	79	90
No paid work	11	8	17	45	21	10
Marital Status (%)						
Single	0	2	47	3	6	41
Married or with partner	96	91	37	93	77	45
Previously married	4	7	16	4	18	14
Number of children (%)						
1 child	22	29	0	20	26	0
> 1 child	78	71	0	78	74	0
Physical activity (min/day)						
Sedentary	770 ± 100	770 ± 100	760 ± 100	710 ± 90	740 ± 80	780 ± 80
Light-intensity activity	230 ± 80	220 ± 80	220 ± 80	290 ± 80	250 ± 70	210 ± 70
MVPA	13 ± 11	17 ± 14	18 ± 15	9 ± 8	14 ± 12	14 ± 12

Measures of centrality and dispersion are mean ± SD.

**Table E2.** Characteristics of the participants in the high age tertile sorted by men and women with and without children at home.

	Men			Women		
	Young child (n = 13)	Older child (n = 68)	No child (n = 177)	Young child (n = 11)	Older child (n = 88)	No child (n = 248)
Age (y)	58 ± 4	57 ± 4	61 ± 5	59 ± 7	55 ± 3	61 ± 5
Ethnicity (%)						
Maori/Pacific	8	12	6	45	14	8
Asian	15	3	2	0	9	5
European	77	85	92	55	77	87
Bachelor degree (%)	38	40	27	0	43	35
Income per adult (\$000)	35 ± 19	42 ± 22	40 ± 21	19 ± 9	39 ± 25	40 ± 24
Work Status (%)						
Paid work	92	91	88	64	80	81
No paid work	8	9	12	36	20	19
Marital Status (%)						
Single	0	4	12	9	6	11
Married or with partner	77	85	67	64	72	55
Previously married	23	10	21	27	23	34
Number of children (%)						
1 child	46	62	0	27	58	0
> 1 child	54	38	0	73	42	0
Physical activity (min/day)						
Sedentary	780 ± 100	770 ± 100	770 ± 100	760 ± 90	740 ± 90	770 ± 90
Light-intensity activity	1230 ± 80	220 ± 90	220 ± 90	240 ± 80	250 ± 80	220 ± 80
MVPA	12 ± 12	13 ± 13	14 ± 14	10 ± 8	13 ± 10	12 ± 10

Measures of centrality and dispersion are mean ± SD.

**Table E3.** Differences in light, moderate, and total steps per day on work days and non-work days among men and women with and without children at home, in the mid-age tertile.

	Men				Women			
	Young child (n = 54)	Older child (n = 97)	No child (n = 87)	Btwn-subject SD	Young child (n = 95)	Older child (n = 180)	No child (n = 92)	Btwn-subject SD
Light steps per day								
Work day								
Mean ± SD	6,600	6,500	7,300	± 3,500	7,400	7,300	6,700	± 3,600
Difference		-50	-680			-70	-680	
±99% CL		±1,600	±1,700			±1,300	±1,500	
Inference		Trivial	Small↑*			Trivial	Trivial <sup>0</sup>	
Non-work day								
Mean ± SD	7,900	7,200	7,100	± 3,700	8,000	7,700	7,200	± 3,600
Difference		-710	-750			-240	-730	
±99% CL		±2000	±2100			±1,500	±1,700	
Inference		Trivial <sup>0</sup>	Small↓*			Trivial <sup>0</sup>	Small↓*	
Moderate steps per day								
Work day								
Mean ± SD	2,600	2,900	3,300	± 2,300	2,200	3,000	3,400	± 1,700
Difference		360	770			750	1,200	
±99% CL		±1,200	±1,300			±780	±920	
Inference		Trivial <sup>0</sup>	Small↑*			Small↑**	Mod.↑**	
Non-work day								
Mean ± SD	1,700	3,100	3,600	± 2,700	2,800	3,000	3,000	± 1,800
Difference		1,400	2,000			190	270	
±99% CL		±1,800	±1,900			±1,100	±1,300	
Inference		Small↑**	Mod.↑**			Trivial	Trivial	
Total steps per day								
Work day								
Mean ± SD	9,100	9,400	10,600	± 4,700	9,600	10,300	10,100	± 4,300
Difference		310	1,500			700	480	
±99% CL		±2,300	±2,400			±1,600	±1,900	
Inference		Trivial	Small↑**			Trivial <sup>0</sup>	Trivial <sup>0</sup>	
Non-work day								
Mean ± SD	9,600	10,200	10,800	± 5,300	10,800	10,700	10,300	± 4,400
Difference		660	1,200			-50	-510	
±99% CL		±3,700	±2,200			±2,000	±2,300	
Inference		Trivial	Small↑*			Trivial	Trivial	

Inferences are based on uncertainty in the difference in relation to the smallest important difference of 0.20 between-subject SD. Arrows indicate the direction of the difference from the group with a young child at home. Asterisks indicate inferential comparisons as follows: clear substantial difference at the \*90% and \*\*99% level, and clear trivial difference at the <sup>0</sup>90% and <sup>00</sup>99% level. All other differences are unclear. The magnitude of difference (difference in means divided by between-subject SD) was determined as follows: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate (mod.); ≥ 1.20, large.

**Table E4.** Differences in light, moderate, and total steps per day on work days and non-work days among men and women with and without children at home, in the high-age tertile.

	Men				Women			
	Young child ( <i>n</i> = 13)	Older child ( <i>n</i> = 68)	No child ( <i>n</i> = 177)	Btwn-subject <i>SD</i>	Young child ( <i>n</i> = 11)	Older child ( <i>n</i> = 88)	No child ( <i>n</i> = 248)	Btwn-subject <i>SD</i>
Light steps per day								
Work day								
Mean ± <i>SD</i>	5,400	6,900	6,800	± 4,200	7,400	7,500	7,100	± 3,900
Difference		1,500	1,400			100	-290	
±99% CL		±3,400	±3,200			±3,400	±3,300	
Inference		Small↑*	Small↑*			Trivial	Trivial	
Non-work day								
Mean ± <i>SD</i>	5,300	7,000	7,100	± 3,500	9,200	7,500	7,100	± 3,500
Difference		1,700	1,800			-1,700	-2,100	
±99% CL		±3,000	±2,900			±3,600	±3,500	
Inference		Small↑*	Small↑*			Small↓*	Mod.↓*	
Moderate steps per day								
Work day								
Mean ± <i>SD</i>	2,700	2,700	3,000	± 2,200	2,500	2,700	3,200	± 1,900
Difference		0	370			140	660	
±99% CL		±2,100	±2,000			±2,100	±2,000	
Inference		Trivial	Trivial			Trivial	Small↑	
Non-work day								
Mean ± <i>SD</i>	1,800	2,300	3,200	± 2,000	2,400	3,700	3,800	± 2,200
Difference		560	1,500			1,300	1,400	
±99% CL		±2,300	±2,200			±3,200	±3,100	
Inference		Small↑	Mod.↑*			Mod.↑	Mod.↑	
Total steps per day								
Work day								
Mean ± <i>SD</i>	8,000	9,600	9,900	± 5,100	9,900	10,100	10,200	± 4,600
Difference		1,500	1,900			270	370	
±99% CL		±4,300	±4,100			±4,200	±4,100	
Inference		Small↑	Small↑*			Trivial	Trivial	
Non-work day								
Mean ± <i>SD</i>	7,000	9,300	10,300	± 4,500	11,500	11,300	10,900	± 4,300
Difference		2,200	3,300			-150	-560	
±99% CL		±4,200	±4,000			±5,000	±4,900	
Inference		Small↑*	Mod.↑**			Trivial	Trivial	

Inferences are based on uncertainty in the difference in relation to the smallest important difference of 0.20 between-subject *SD*. Arrows indicate the direction of the difference from the group with a young child at home. Asterisks indicate inferential comparisons as follows: clear substantial difference at the \*90% and \*\*99% level, and clear trivial difference at the <sup>0</sup>90% and <sup>00</sup>99% level. All other differences are unclear. The magnitude of difference (difference in means divided by between-subject *SD*) was determined as follows: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate (mod.); ≥ 1.20, large.



**Table E5.** Differences in proportion (%) of time spent in sedentary, light, and moderate-to-vigorous intensities on work days and non-work days among men and women with and without children at home, in the mid-age tertile.

	Men			Women		
	Young child ( <i>n</i> = 54)	Older child ( <i>n</i> = 97)	No child ( <i>n</i> = 87)	Young child ( <i>n</i> = 95)	Older child ( <i>n</i> = 180)	No child ( <i>n</i> = 92)
Sedentary time						
Work day						
Mean ± <i>SD</i>	75.0 ± 9.7	75.2 ± 9.6	74.5 ± 9.8	69.3 ± 8.9	72.6 ± 8.3	76.6 ± 7.5
Diff; ±99% CL		0.1; ±4.6	-0.5; ±4.8		3.4; ±3.2	7.3; ±3.7
Inference		Trivial	Trivial		Small↑**	Moderate↑**
Non-work day						
Mean ± <i>SD</i>	70.8 ± 9.3	72.9 ± 9	74.2 ± 8.7	68.5 ± 8.7	71.5 ± 8.3	75.7 ± 7.5
Diff; ±99% CL		2.0; ±5.7	3.4; ±5.9		3.0; ±3.9	7.2; ±4.4
Inference		Small↑*	Small↑*		Small↑**	Moderate↑**
Light-intensity activity						
Work day						
Mean ± <i>SD</i>	22.2 ± 8.3	21.5 ± 8.1	21.6 ± 8.2	28.2 ± 8.1	24.2 ± 7.3	20.2 ± 6.5
Diff; ±99% CL		-0.7; ±4	-0.6; ±4.1		-4.0; ±2.9	-8.0; ±3.3
Inference		Trivial	Trivial		Small↓**	Moderate↓**
Non-work day						
Mean ± <i>SD</i>	27.1 ± 8.3	23.7 ± 7.6	21.8 ± 7.2	28.8 ± 7.7	25.4 ± 7.2	21.6 ± 6.4
Diff; ±99% CL		-3.4; ±4.9	-5.3; ±5.2		-3.4; ±3.4	-7.1; ±3.9
Inference		Small↓**	Moderate↓**		Small↓**	Moderate↓**
MVPA						
Work day						
Mean ± <i>SD</i>	1.3 ± 1.1	1.7 ± 1.4	1.8 ± 1.5	0.9 ± 0.8	1.4 ± 1.2	1.4 ± 1.2
Diff; ±99% CL		0.4; ±0.5	0.5; ±0.5		0.5; ±0.3	0.5; ±0.3
Inference		Small↑**	Small↑**		Small↑**	Small↑**
Non-work day						
Mean ± <i>SD</i>	0.9 ± 0.5	1.2 ± 0.6	1.5 ± 0.8	0.7 ± 0.4	1.1 ± 0.6	1.0 ± 0.5
Diff; ±99% CL		0.3; ±0.5	0.5; ±0.5		0.3; ±0.3	0.2; ±0.3
Inference		Small↑*	Moderate↑**		Moderate↑**	Small↑*

Inferences are based on uncertainty in the difference in relation to the smallest important difference of 0.20 between-subject *SD*. Arrows indicate the direction of the difference from the group with a young child at home.. Asterisks indicate inferential comparisons as follows: clear substantial difference at the \*90% and \*\*99% level, and clear trivial difference at the 090% and 0099% level. All other differences are unclear. The magnitude of difference (difference in means divided by between-subject *SD*) was determined as follows: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate; ≥ 1.20, large.

**Table E6.** Differences in proportion (%) of time spent in sedentary, light, and moderate-to-vigorous intensities on work days and non-work days among men and women with and without children at home, in the high-age tertile.

	Men			Women		
	Young child ( <i>n</i> = 13)	Older child ( <i>n</i> = 68)	No child ( <i>n</i> = 177)	Young child ( <i>n</i> = 11)	Older child ( <i>n</i> = 88)	No child ( <i>n</i> = 248)
Sedentary time						
Work day						
Mean ± <i>SD</i>	76.3 ± 9.8	75.9 ± 9.9	75.3 ± 10.0	74.1 ± 8.8	72.8 ± 9.1	75.4 ± 8.5
Diff; ±99% CL		-0.4; ±8.1	-1.1; ±7.8		-1.3; ±8.0	1.3; ±7.7
Inference		Trivial	Trivial		Trivial	Trivial
Non-work day						
Mean ± <i>SD</i>	77.2 ± 8.2	74.9 ± 8.7	75.1 ± 8.7	69.6 ± 9.1	70.6 ± 8.9	74.8 ± 8.2
Diff; ±99% CL		-2.3; ±7.7	-2.1; ±7.3		1.1; ±10.0	5.2; ±10.0
Inference		Small↓	Small↓		Trivial	Small↑*
Light-intensity activity						
Work day						
Mean ± <i>SD</i>	21.0 ± 8.3	21.3 ± 8.4	21.4 ± 8.4	23.4 ± 7.8	24.3 ± 8.0	21.6 ± 7.4
Diff; ± 99% CL		0.3; ±6.9	0.4; ±6.6		0.9; ±7.0	-1.9; ±6.8
Inference		Trivial	Trivial		Trivial	Small↓
Non-work day						
Mean ± <i>SD</i>	21.2 ± 7.0	22.5 ± 7.3	21.5 ± 7.0	28.0 ± 8.2	25.7 ± 7.8	21.6 ± 6.9
Diff; ±99% CL		1.3; ±6.6	0.3; ±6.3		-2.3; ±9.3	-6.3; ±9.0
Inference		Trivial	Trivial		Small↓	Moderate↓*
MVPA						
Work day						
Mean ± <i>SD</i>	1.2 ± 1.2	1.3 ± 1.3	1.4 ± 1.4	1.0 ± 0.8	1.3 ± 1.0	1.2 ± 1.0
Diff; ±99% CL		0.0; ±1.1	0.2; ±1.0		0.3; ±0.8	0.2; ±0.8
Inference		Trivial	Trivial		Small↑	Small↑
Non-work day						
Mean ± <i>SD</i>	0.5 ± 0.4	1.1 ± 0.9	1.2 ± 1.0	0.2 ± 0.1	0.9 ± 0.7	1.0 ± 0.7
Diff; ±99% CL		0.6; ±0.5	0.8; ±0.4		0.7; ±0.2	0.8; ±0.2
Inference		Moderate↑*	Large↑**		Large↑**	Large↑**

Inferences are based on uncertainty in the difference in relation to the smallest important difference of 0.20 between-subject *SD*. Arrows indicate the direction of the difference from the group with a young child at home.. Asterisks indicate inferential comparisons as follows: clear substantial difference at the \*90% and \*\*99% level, and clear trivial difference at the <sup>0</sup>90% and <sup>00</sup>99% level. All other differences are unclear. The magnitude of difference (difference in means divided by between-subject *SD*) was determined as follows: < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate; ≥ 1.20, large

## Appendix F Hour-by-hour activity profiles

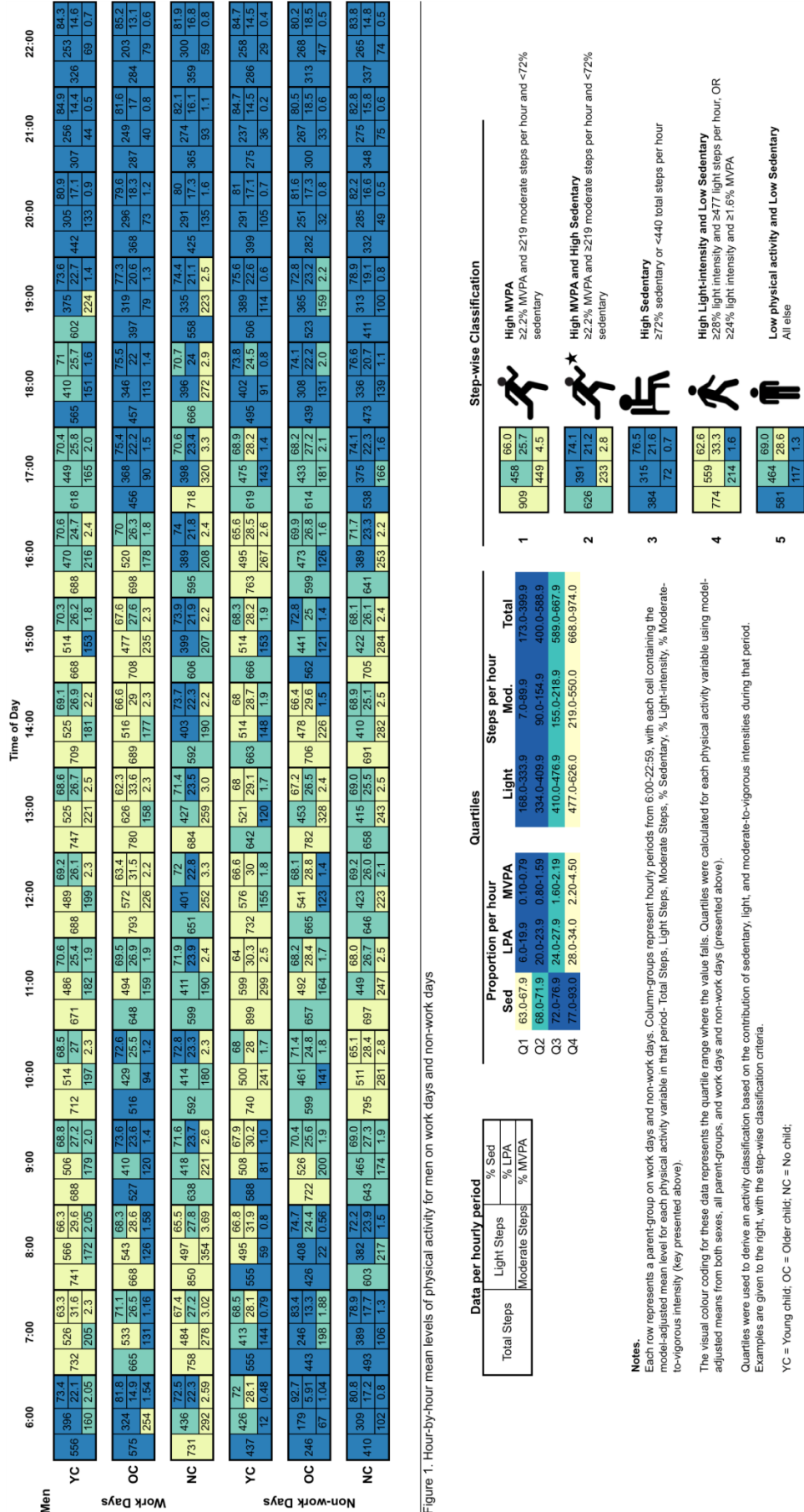
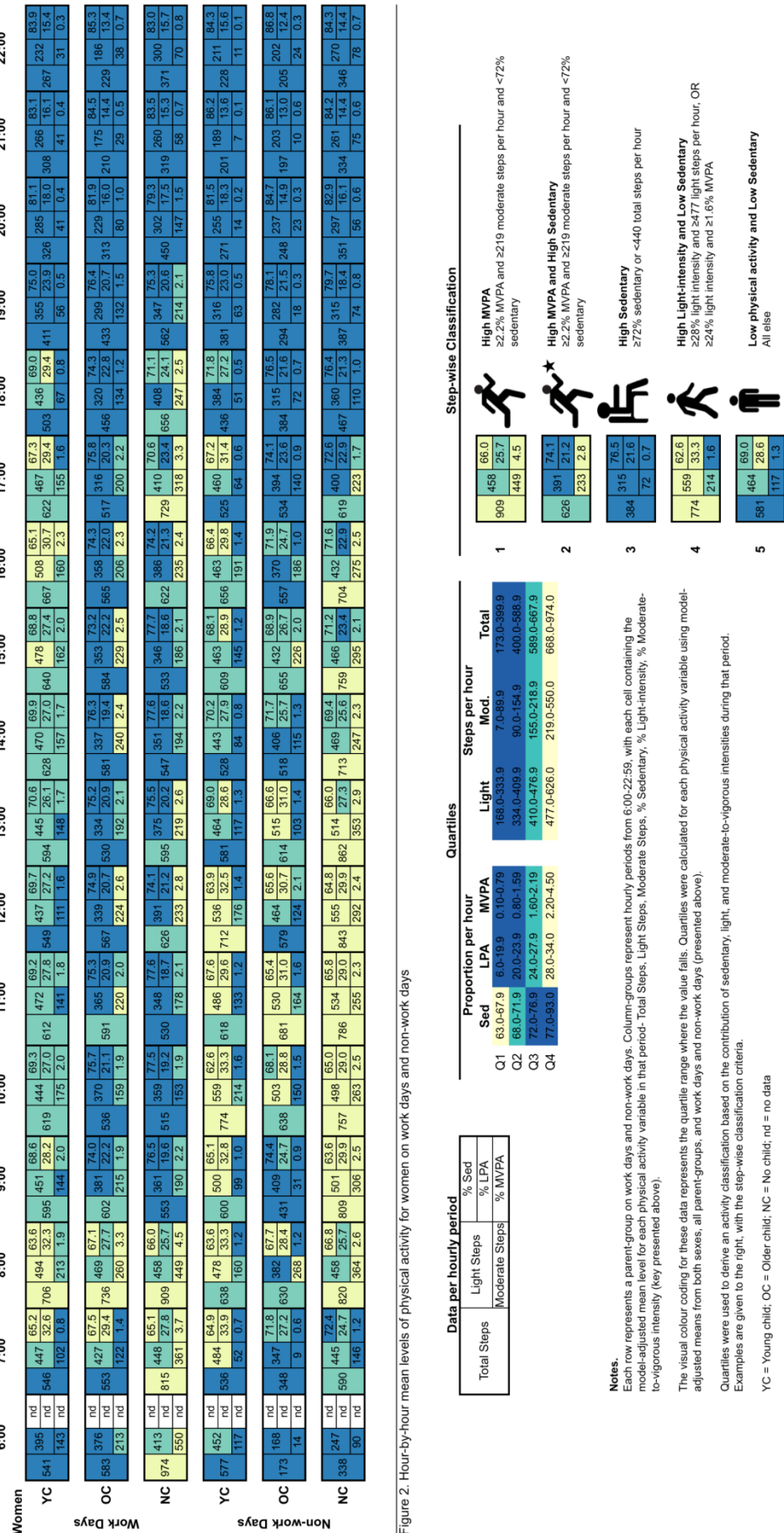


Figure 1. Hour-by-hour mean levels of physical activity for men on work days and non-work days



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## **Measuring Physical Activity and Sedentary Behaviors in Women with Young Children: A Systematic Review**

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*Current evidence indicates that women with young children are less active than women without children. In this review the authors investigated the methods of measuring physical activity employed in studies of women with young children (aged 1–5 years) and the associated challenges in measurement. Articles from databases (MEDLINE, OVID, CINAHL, Google Scholar) and manual searches were limited to English peer-reviewed journals published from 1990 to 2010. Studies that included measurement of physical activity in samples of women with young children were selected. Measurement properties were extracted, and original reliability and validity articles were reviewed for physical activity measurement tools used by 15 samples. The evidence base was dominated by self-report measurement tools, many of which assessed leisure-time physical activity only. Use of motion sensors to assess physical activity in this population was limited. It is likely that much of the habitual physical activity performed by women with young children has not been captured by self-report measures. Further investigation should be undertaken using tools that capture adequately all health-enhancing physical activity among women with young children.*

**KEYWORDS** *women, mothers, children, dependents, physical activity, measurement, self-report*

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## INTRODUCTION

It is well-documented that physical activity is beneficial for maintaining health and quality of life. The benefits of regular physical activity for women's health and well-being are extensive, including the prevention of cardiovascular disease, diabetes, and some cancers (Brown, Burton, & Rowan, 2007). In the short term, attaining recommended levels of physical activity can improve quality of life (Brown, Balluz, et al., 2003; Vuillemin et al., 2005; Wolin et al., 2007) and reduce likelihood of sleeping difficulties, back pain, tiredness, and depressive symptoms among women (Augestad, Slettemoen, & Flanders, 2008; Brown et al., 2000; Craike, Coleman, & MacMahon, 2010; Teychenne, Ball, & Salmon, 2008a; 2008b). Furthermore, the benefits of leading a physically active lifestyle extend beyond the individual to the family unit; being physically active with partners and/or children may positively influence familial relationships while providing important active role models for children (Lewis & Ridge, 2005). Indeed, parental physical activity has been associated positively with physical activity levels of young children (Oliver, Schofield, & Schluter, 2010). Despite these pertinent benefits, Bellows-Riecken and Rhodes' (2008) review of physical activity in parenthood showed that the results of a number of studies indicate that women with young children (WYC) were less active than their childless counterparts. Longitudinally, physical activity has been shown to decrease during the transition to motherhood (Bell & Lee, 2005; Brown, Heesch, & Miller, 2009; Brown & Trost, 2003); not returning to original levels (Bellows-Riecken & Rhodes, 2008).

A great deal of literature has focused on physical activities performed by the general adult population, however, WYC might differ significantly in the way they accumulate daily physical activity. The most signifying element of WYC is their role of responsibility. Essentially, this responsibility places boundaries around the freedom of choice of daily and leisure-time activities. While an adult is caring for a child it is possible for him/her to perform other tasks, yet the choice of these activities is severely constrained (Craig & Bittman, 2008). Activities tend to be intermittent, less structured, concurrent, and of light-to-moderate intensity (Collins, Marshall, & Miller, 2007; Scharff et al., 1999). During times when an adult is relieved of immediate childcare responsibility, qualitative research has shown that mothers continue to feel constraint in the legitimate use of their time, with the feeling that time belongs to others (Drew & Paradise, 1996). This role of responsibility has the potential to impact severely the time available to participate in physical activity at recommended levels sufficient for health benefit. Women in the postnatal period with children aged under 12 months may experience further constraints upon their time with significant time demands for feeding and caring for a dependent baby (McVeigh, 1997).



For all WYC, overall daily energy expenditure is likely to be a sporadic accumulation of light-to-moderate intensity activity, rather than planned continuous bouts of moderate-to-vigorous intensity physical activity (MVPA). Current World Health Organization (2010) recommendations state that health may be improved through participation in at least 150 minutes of moderate-intensity or at least 75 minutes of vigorous-intensity aerobic activity throughout a week (or an equivalent combination of moderate- and vigorous-intensity activity). In addition, muscle strengthening activities should be completed on two or more days a week. These recommendations include activities performed during leisure time physical activity, transportation, occupation, household chores, play, games, sports, and planned exercise. In an Australian sample of WYC aged 5 years and younger, more than 64% reported less than 150 minutes of active leisure per week (Brown *et al.*, 2001). Similarly, United States intervention participants reported pre-test mean of  $70 \pm 35.93$  minutes of physical activity per week (Fahrenwald *et al.*, 2004).

Meanwhile, interest is growing in the health benefits of all non-sedentary behaviors (Levine *et al.*, 2008; Levine, Schleusner, & Jensen, 2000; Weller & Corey, 1998), and conversely, the poor health outcomes associated with sedentary behaviors, such as sitting (Brown, Bauman, & Owen, 2009; Hamilton, Hamilton, & Zderic, 2007; Healy *et al.*, 2008; Katzmarzyk *et al.*, 2009). Significant energy may be expended in activities such as free-living walking or short bouts (<15 minutes) of low-velocity (~1 mph) walking (Levine *et al.*, 2008). Further, an independent association between sitting time and mortality rates from all causes and cardiovascular disease has been shown (Katzmarzyk *et al.*, 2009).

Despite current evidence indicating that WYC are less active than their childless counterparts, comprehensive information is lacking about the patterns of habitual physical activity that WYC accumulate and the time this population spends in sedentary pursuits. It is important to consider the contribution physical activity in non-leisure domains (e.g., household, transport) make to WYC's overall physical activity. Application of self-report tools among WYC may be problematic; many self-report tools inadequately capture physical activities in non-leisure domains and among adult populations have been shown to misrepresent total activity as measured by objective measures (accelerometer and pedometer) (Mackay, Schofield, & Schluter, 2007; Prince *et al.*, 2008). This effect may be more pronounced among WYC, given the likelihood that a significant amount of time is spent in sporadic, concurrent, and unstructured activities.

Researchers have developed interest in the complexities of measuring physical activity amongst WYC, and a range of measures have been utilized. Whilst efforts have been made to develop measures that capture physical activity and inactivity across the spectrum, this area of measurement research is still in its infancy. To understand accurately the prevalence of physical ac-

tivity (i.e., frequency, duration, and intensity of physical activity), associated health outcomes, and moderators of physical activity in WYC, it is critical that measurement tools employed in this population appropriately capture the broad spectrum of active and inactive behaviors (Brown, Bauman, et al., 2009; Hallal & Ekelund, 2010).

The purposes of the authors in this review were to: (1) investigate the methods that have been used to assess physical activity in WYC, (2) identify the effect of differing methods on data on prevalence of physical activity, (3) outline physical activity measurement issues specific to this population, and (4) suggest how measurement methodology may be refined to better understand the physical activity behaviors of WYC.

## METHODS

Computer searches (MEDLINE, OVID, CINAHL, Google Scholar) and manual searches were conducted of articles in the English language literature from 1990 to June 2010. Literature prior to 1990 was excluded based on significant advancements in physical activity measurement over the previous two decades, including widespread use of accelerometry. Keywords for the searches included: 'physical activity,' 'exercise,' 'leisure,' 'recreation,' 'sedentary,' 'measure,' 'accelerometer,' 'survey,' 'self-report,' 'valid,' 'reliable,' 'pedometer,' 'parent,' 'mother,' 'women,' 'dependent,' 'child.' Search terms included a combination of keywords, for example 'physical activity' AND ('measure' OR 'self-report,' OR 'accelerometer' OR 'pedometer') AND ('mother' OR 'parent'). Only published articles in refereed journals and electronic manuscripts accepted for publication in refereed journals published ahead of print were considered for this review. Studies that assessed physical activity in samples of WYC (children aged 1–5 years), or in which a physical activity measurement tool was assessed with WYC were included. Articles focusing on the immediate postpartum period (0–12 months) were excluded as this life stage has significantly unique characteristics and subsequent constraints on maternal activity; however, studies were considered if the sample included both children aged <12 months as well as 1–5 years. Similarly, studies that included both children aged 1–5 years and children aged >5 years were considered in this review.

Physical activity measurement tools were defined as those that assess physical activity frequency, duration, and/or intensity; tools that assessed fitness attributes, such as maximal oxygen uptake (VO<sub>2</sub> max) or flexibility, were excluded. Measurement properties of physical activity tools (construct, domain, recall, parameters, format, items, score, unit), sample characteristics, and key activity findings were extracted from included studies, and original reliability and validity papers were identified and reviewed for measurement tools used by independent studies.



## RESULTS

Of the 18 studies included in this review, 15 were from independent study samples. Two studies used the same sample of WYC enrolled in the Moms on the Move intervention in the United States (Fahrenwald, Atwood, & Johnson, 2005; Fahrenwald et al., 2004); two studies analyzed a sample of WYC participating in an intervention trial (Brown, Miller, & Miller, 2003; Miller, Trost, & Brown, 2002); and two studies analyzed a sample of 1,113 Canadian women (Verhoef & Love, 1992; 1994). Reference hereafter will be made to the measurement tools used in the independent samples ( $n = 15$ ). Twelve studies assessed physical activity in samples of WYC, while six studies analyzed data from a sub-sample of WYC drawn from larger women's or adult studies. The majority of studies was cross-sectional, had small samples, was published after 2003, and used self-report measures of physical activity. Seven studies specifically considered mothers of preschool children (aged <5 years), whilst the remaining studies included mothers of children across the age spectrum of 0–18 years (Table 1).

### Self-Reported Physical Activity

Self-report measures of physical activity dominated the literature with 14 independent samples using varying forms of interviewer-administered or self-administered questionnaires. The current review identified three key self-report instruments used by nine independent studies: 7-day Physical Activity Recall (PAR), Godin Leisure-Time Exercise Questionnaire (LTEQ), and the Australian Women's Activity Survey (AWAS). Of the remaining studies, two drew data from large national studies (Young, Cunningham, & Buist, 2005; Young, James, & Cunningham, 2004) and one from a birth cohort study (Craike et al., 2010), for which physical activity questions were a subsection; and two independent studies modified questions from national physical activity questionnaires (Brown et al., 2001; Brown, Miller, et al., 2003; Miller, Trost, & Brown, 2002).

### Content Validity

Content validity refers to the appropriateness of the tool to measure the construct in question. In this case, the construct referred to overall daily physical activity, which may be undertaken in all domains, including occupation, transport, household, leisure and planned exercise (World Health Organization, 2010). Leisure-time, sport, and exercise activity dominated the measurement tools employed in WYC samples (Table 2). Less than half the instruments additionally captured physical activity performed in other domains, including occupational ( $n = 3$ ), transportation ( $n = 3$ ), household ( $n = 2$ ), sitting ( $n = 2$ ), sleeping ( $n = 1$ ), and childcare ( $n = 1$ ).

**TABLE 1** Methodological Attributes and Key Activity Findings of Included Studies

Measure tool reference	Year	Study design	Sample (n; mean age or range)	Sample characteristics	Age of children	Key activity findings
Self-report: 1994 NSW Health Promotion Survey: Brown, Brown, Miller, & Hansen	2001	Cross-sectional	554; 33y	Mothers	≤5y	>66% mothers reported <150 minutes active leisure/week.
Active Australia—Modified: Brown, Miller, & Miller <sup>a</sup>	2003	Cross-sectional	529; 18–64y (mothers) 185; 18–64y; 60% female (workers)	Separate sample mothers and 'workers'	<5y 5–18y	Mothers participate in less physical activity than a sample of workers. No physical activity 14.1%; 11.9%, respectively ( $p < 0.05$ ). <150 minutes/week 37.2%; 28.6%, respectively ( $p < 0.05$ ). >150 minutes/week 48.7%; 59.5%, respectively ( $p < 0.05$ ). Mothers spend less time sitting per day than sample of workers $3.5 \pm 2.20$ and $9.4 \pm 2.40$ hours, respectively. At follow-up, intervention groups were more likely to meet current guidelines.
Miller, Trost, & Brown <sup>a</sup>	2002	Intervention	554; 32.8y	Mothers	<2y ≥5y	Control 46.3% Intervention 1 50.4% Intervention 2 59.9%

(continued)

**TABLE 1** Methodological Attributes and Key Activity Findings of Included Studies (*Continued*)

Measure tool reference	Year	Study design	Sample (n; mean age or range)	Sample characteristics	Age of children	Key activity findings
Australian Women's Activity Survey: Fieldsoe, Marshall, & Miller	2009	Reliability and Validity	40; 33y reliability protocol 75; 32y validity protocol	Mothers	≤5y	Women participate in 180 ± 361 minutes HEPA/week.
Godin Leisure-time Exercise Questionnaire: McIntyre & Rhodes	2009	Cross-sectional (retrospective)	139; 31.2y	Mothers	0–4y	Weekly exercise decreased after becoming a parent. Before parenthood: 249.74 ± 209.62 minutes/week total physical activity. After parenthood: 169.89 ± 184.53 minutes/week total physical activity $F = 17.05$ ( $p < 0.01$ ).
Tavares, Plotnikoff, & Loucaides	2009	Cross-sectional	302; 41y (Mothers) 881; 46y (Non-mothers)	Occupational women	<13y	Women with children less 'active' (≥600 METs/week) than women without children (54% and 58% respectively). Weekly EE was lower for women with children (587 ± 688.24 METs) than women without children (647 ± 704.36), $t = -1.27$ ( $p < 0.21$ ).

Measure tool reference	Year	Study design	Sample (n; mean age or range)	Sample characteristics	Age of children	Key activity findings
Verhoef & Love <sup>c</sup>	1992	Cross-sectional	1,113; 20–49y	Women's study, mothers 56.2%	<17y	49.0% and 61.8% mothers and non-mothers exercise, respectively ( $p < 0.001$ ). 20.8% and 37.2% mothers and non-mothers are very active ( $\geq 90$ minutes/week), respectively ( $p < 0.001$ ).
Verhoef & Love <sup>c</sup>	1994	Cross-sectional	1,113; 20–49y	Women's study, mothers 44%	<17y	Mothers participate in less strenuous and moderate activity than non-mothers. Strenuous 28.6%; 44.4% ( $p < 0.01$ ). Moderate 55.1%; 68.8% ( $p < 0.01$ ). Mild 64.4%; 66.3% ( $p > 0.01$ ).
National Population Health Survey, Canada: Young, James, & Cunningham	2004	Cross-sectional	2,184;	Sub-sample of mothers drawn from national study	<18y	No differences in physical activity between lone and partnered mothers, 45.3% and 41.4% 'active,' respectively ( $p \geq 0.05$ ).
Parent 1 Self-complete Questionnaire, Australia: Craike, Coleman, & MacMahon	2010	Cross-sectional	4,702; 34.6y	Mothers of infants cohort	3–19 months	Mothers participate in $2.77 \pm 1.89$ (range 0–7) days physical activity $\geq 30$ minutes/week.

(continued)

**TABLE 1** Methodological Attributes and Key Activity Findings of Included Studies (*Continued*)

Measure tool reference	Year	Study design	Sample (n; mean age or range)	Sample characteristics	Age of children	Key activity findings
Seven-day Physical Activity Recall (PAR): Fahrenwald & Walker	2003	Cross-sectional	30; 24.33y	Mothers	Dependents	Stage of change was significantly related to minutes of moderate to very hard physical activity ( $r_s = 0.81, p < 0.01$ ). Pre-contemplation ( $n = 6$ ), $2.85 \pm 4.78$ minutes/day. Contemplation ( $n = 6$ ), $6.07 \pm 6.75$ minutes/day. Preparation ( $n = 6$ ), $10.47 \pm 7.25$ minutes/day. Active ( $n = 6$ ), $42.50 \pm 21.37$ minutes/day. Maintenance ( $n = 6$ ), $37.26 \pm 20.62$ minutes/day. The experimental group significantly increased moderate physical activity ( $p < 0.001, d = 2.07$ ). Study sample pre-test mean = $70.00 \pm 35.93$ minutes/week. Experimental group mean change = $88.18 \pm 45.94$ minutes/week. Control group change mean change = $1.14 \pm 38.05$ minutes/week. Prevalence not reported.
Fahrenwald et al. <sup>b</sup>	2004	Intervention	44; 26.5y	Mothers	Dependents	
Fahrenwald et al. <sup>b</sup>	2005	Intervention	44; 26.5y	Mothers	Dependents	



Measure tool reference	Year	Study design	Sample (n; mean age or range)	Sample characteristics	Age of children	Key activity findings
Fahrenwald & Shangreux	2006	Cross-sectional	30; 21.3y	Mothers	Dependents	Among sample of American Indian mothers, stage of change was significantly related to minutes of moderate to very hard physical activity ( $r_s = 0.74, p < 0.01$ ). Pre-contemplation ( $n = 6$ ), $2.85 \pm 4.78$ minutes/day. Contemplation ( $n = 6$ ), $6.07 \pm 6.75$ minutes/day. Preparation ( $n = 6$ ), $10.47 \pm 7.25$ minutes/day. Active ( $n = 6$ ), $42.50 \pm 21.37$ minutes/day. Maintenance ( $n = 6$ ), $37.26 \pm 20.62$ minutes/day.
Sallis et al.	2001	Longitudinal	226; 31–32y	Mothers	4y	European-American mothers reported more vigorous leisure ( $p < 0.005$ ), but less moderate work ( $p < 0.02$ ) than Mexican American mothers. There were no differences in moderate leisure ( $p < 0.91$ ) or vigorous work ( $p < 0.13$ ) activities. Mean baseline physical activity $32.9 \pm 1.3 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{day}^{-1}$ . Mothers significantly increased energy expenditure from baseline to 10-weeks ( $t = 2.36, p < 0.05$ ).
Urizar et al.	2005	Intervention	68; 31.7y	Sub-sample of mothers drawn from women's study	$\leq 5y$ 6–18y	

(continued)

**TABLE 1** Methodological Attributes and Key Activity Findings of Included Studies (*Continued*)

Measure tool reference	Year	Study design	Sample (n; mean age or range)	Sample characteristics	Age of children	Key activity findings
U.S. National Health and Nutrition Examination Survey III: Young, Cunningham, & Buist	2005	Cross-sectional	1,446; 17–59y	Sub-sample of mothers drawn from national study	<17y	More lone mothers participate in $\geq 20$ bouts ( $\geq 30$ mins) of physical activity per month than partnered mothers; 35.8% and 29.9%, respectively.
Pedometer: Yamax Digi-walker SW-200; Fahrenwald et al.	2004	Intervention	11; 26.5y	Mothers	Dependents	The experimental group increased mean daily step counts from pre-test ( $5,825 \pm 1,847$ steps) to post-test ( $9,181 \pm 1,700$ ) ( $t = 6.16, p < 0.001$ ).
Yamax Digi-walker SW-701; Clarke et al.	2007	Intervention	124; 18–45y	Mothers	1–4y	Low-income women increased mean daily step counts from baseline ( $5,969 \pm 3,123$ ) to post-test ( $9,757 \pm 3,843$ ). At baseline, 11.8% participants achieved $\geq 10,000$ steps/day, increasing to 46.2% at post-test.

Notes. EE = Energy expenditure, METs = Metabolic equivalents, y = Years.

<sup>a</sup>Brown et al., 2003 and Miller et al., 2002 use same dataset for analysis.

<sup>b</sup>Fahrenwald et al., 2004 and Fahrenwald et al., 2005 use same dataset for analysis.

<sup>c</sup>Verhoef & Love, 1992 and 1994 use the same dataset for analysis.

**TABLE 2** Measurement Properties of Self-Report Tools

Tool	Construct dimension	Domains	Recall period	Parameters	Format administration	No. of items/time to complete	Scores	Unit of measurement
1994 NSW Health Promotion Survey	PA	L, O, T	Previous 7 days	D, I	Self-administered	?	Total	Minutes/week
Active Australia—modified	PA	L, T, St	Previous 7 days	F, D (>10 mins), I	Self-administered	24	TEE	MET.minutes/week
Australian Women's Activity Survey	PA	P, H, O, T, C, St	Usual 7 days	F, D, I	Interview	67	Total—P, H, O, T, C Total—Sitting, light, walking, moderate, vigorous; Total activity Total HEPA (w + m + v)	Minutes/week
Godin Leisure-time Exercise Questionnaire	Exercise	E	Usual 7 days	F (>15 mins), I	Self-administered	4	Total, light, moderate, strenuous	Times/week
Parent 1 Self-complete Questionnaire, Australia	LTPA	L	Usual 7 days	F >30 mins	Self-administered	1	0–7	Days
National Population Health Survey, Canada	LTPA	L	Previous 3 months	F, D	Interview	?	TEE	Kcal/kg/day
Seven-day physical activity recall (PAR)	PA	Sp, H, O, S, [St]	Previous 7 days	F, D (>10 mins), I	Interview	~20 mins	Sleep, [sitting], light, moderate, hard, very hard	Minutes/week
U.S. National Health and Nutrition Examination Survey III (1988–1994)	LTPA	L	Previous month	F	Interview	?	Leisure activities	Frequency/month

Notes: C = Childcare, D = Duration, E = Exercise, F = Frequency, H = Household, I = Intensity, L = Leisure, Kcal = Kilo calories, MET = Metabolic equivalent, O = Occupational, P = Planned activities, PA = Physical activity, R = Recreation, S = Sleeping, Sp = Sport, St = Sitting, Sg = Strength exercises, T = Transport, [x] = modified version, ? = unknown.



The AWAS and PAR provided the most comprehensive assessment of physical activity across the spectrum, with leisure-time, household, occupational, transportation, and sitting time included. The AWAS also captured childcare activity, and the PAR considered sleeping time. Further, the AWAS and PAR were the only interviewer-administered studies to be included. The majority of tools captured activity across a seven-day period, with a mix of previous week ( $n = 3$ ) and usual week ( $n = 3$ ) activity. With the exception of four tools, physical activity was scored by duration of activity over the recall period, including total minutes, MET-minutes (metabolic equivalent), and minutes per domain or intensity. Other scores included frequency of participation and total energy expenditure (kilocalories per kilogram per day).

### Reliability and Concurrent Validity

Original reliability and validity studies were sourced for the three key instruments included in this review, and data pertaining to the sample, comparison measures, reliability, and validity were extracted from these studies (Table 3). The Godin LTEQ was validated using VO2 max and body fat; findings showed that strenuous activity was more accurately reported than mild or moderate activity. Similarly, an investigation of test-retest reliability of the Godin LTEQ in a sample of 53 adults also showed strenuous activity was more reliably reported than light and moderate activity (Godin & Shephard, 1985). The PAR has been validated for use in numerous populations, including children and adults. Recently, Wilkinson and colleagues (2004) validated the PAR in a sample of 3-month postpartum women using pedometer steps. Using the Welk algorithm (Welk, Thompson, & Galper, 2001), minutes spent sitting was correlated negatively with pedometer step counts, and minutes spent in light activity and total activity (sum of light-to-very hard activity) was correlated positively with step counts. The authors concluded that obtaining time spent sitting, and extracting this from light activity, may improve the validity of PAR estimation of activity in low-income postpartum women. Additionally, Johnson-Kozlow et al. (2006) compared the agreement of the PAR and another 7-day recall tool (International Physical Activity Questionnaire; IPAQ) with accelerometer data in a sample of breast cancer patients ( $n = 159$ ) and concluded the PAR instrument was superior to the IPAQ in all respects (measurement bias, criterion-related validity, specificity, sensitivity, and agreement). Lately, the AWAS was developed following a systematic review and qualitative exploration of physical activity behaviors of WYC. Data showed the tool provided a reliable measure of physical activity in this population, across all active intensities ( $ICC = 0.66\text{--}0.80$ ), but a lower intraclass correlation coefficient was found for sitting time ( $ICC = 0.42$ ). The AWAS was validated using MTI accelerometer data collected during a 7-day period prior to survey completion. Spearman correlation coefficients were weak across all activity domains (planned, transport, occupational,

**TABLE 3** Reliability and Validity of Self-Report Measures

Tool reference	Reliability sample (n; mean age or range)	Interval	Results	Validity sample (n; mean age or range)	Comparison measure	Results
Seven-day physical activity recall (PAR)						
Sallis 1985	31 <sup>m</sup> , 33 <sup>f</sup> ; 38y	2 week	Vigorous $r = 0.83^{***}$ Moderate $r = 0.75^{***}$	—	—	—
Wilkinson, Huang, Walker, Sterling, & Kim, 2004	—	—	—	44 <sup>f</sup> ; 22.4y 3-month postpartum women	Yamax Digi-walker (SW-200)	Sleep $r = 0.07$ Sitting $r = -0.45^{**}$ Light $r = 0.35^{*}$ Moderate $r = 0.14$ Hard $r = 0.12$ Very Hard $r = -0.10$ Total (L, M, H, VH) $r = 0.40^{**}$ Total activity $r = 0.73^{***}$ Kappa $\kappa = 0.59$ Light $r = 0.04$ [0.06] Moderate $r = 0.03$ [0.06] Strenuous $r = 0.38^{*}$ [0.21 <sup>†</sup> ] Total $r = 0.24^{*}$ [0.21 <sup>†</sup> ] Sweat $r = 0.26^{*}$ [0.21 <sup>†</sup> ] Freedson & Swartz cutpoints <b>Intensity across all domains:</b> Sitting $r_s = 0.32$ [0.32] Light $r_s = 0.12$ [0.09] Brisk walking $r_s = 0.11$ [0.06] Moderate $r_s = 0.07$ [0.09] Vigorous $r_s = 0.07$ [0.09] Total activity $r_s = 0.13$ [0.13]
Johnson-Kozlow, Sallis, Gilpin, Rock, & Pierce, 2006	—	—	—	159 <sup>f</sup> ; 56.6y	Actigraph (MTI) 7164	
Godin Leisure-time Exercise Questionnaire	53;	2 week	Light $r = 0.48^{*}$ Moderate $r = 0.46^{*}$ Strenuous $r = 0.54^{*}$ Total $r = 0.74^{*}$ Sweat $r = 0.80^{*}$	163 <sup>m</sup> , 143 <sup>f</sup> ; 18–65y	Maximum oxygen consumption (VO <sub>2</sub> max) [Body fat]	
Australian Women's Activity Survey (AWAS)	40 <sup>f</sup> ; 33y Women with $\geq 1$ child aged $\leq 5y$	7 day	<b>Intensity:</b> Sitting ICC = 0.42 Light ICC = 0.66 Brisk walking ICC = 0.68 Moderate ICC = 0.74 Vigorous ICC = 0.66 HEPA ICC = 0.80 <b>Domain:</b> Planned ICC = 0.79 Occupational ICC = 0.74 Childcare ICC = 0.68 Domestic ICC = 0.62 Transport ICC = 0.63	75 <sup>f</sup> ; 32y Women with $\geq 1$ child aged $\leq 5y$ .	MTI Accelerometer Worn 7 days prior to survey	
Feldsoe, Marshall, & Miller, 2009	—	—	—	—	—	

Notes. <sup>f</sup> = female, <sup>m</sup> = male, H = hard, ICC = Interclass correlation coefficient, L = Light, M = Moderate,  $r$  = Pearson correlation coefficient,  $r_s$  = Spearman correlation coefficient, VH = Very hard, y = Years,  $^{*}p < 0.05$ ,  $^{**}p < 0.01$ ,  $^{***}p < 0.001$ .



household, childcare) at each intensity level ( $r_s = 0.06\text{--}0.13$ ), although a moderate association was found for sitting time ( $r_s = 0.32$ ). Moderate- and vigorous-intensity activity in the planned and transport domains showed coefficients comparable with other self-report tools used among the general population ( $r_s = 0.22\text{--}0.36$ ) (Fjeldsoe, Marshall, & Miller, 2009).

### Motion Sensors

Motion sensors (e.g., accelerometers, pedometers) are small devices that capture movements providing an objective method for assessing accumulated activity. Accelerometers use piezoelectricity to register acceleration, recording detailed temporal data across the spectrum of activity intensity. Pedometers are small hip-worn devices that quantify physical activity by capturing all ambulatory activity in terms of accumulated steps. No studies incorporated accelerometers in their measurement methodology, and only two studies assessed physical activity using pedometers (Table 1). Clarke et al. (2007) employed the Yamax Digiwalker SW-701 (Yamax Corp., Minato-ku, Tokyo, Japan) to evaluate the effectiveness of an intervention to increase physical activity among overweight and obese low-income mothers. Fahrenwald et al. (2004) assessed physical activity with the Yamax Digi-Walker SW-200 Step Counter® (New Lifestyles, Kansas City, MO) at baseline and post-intervention in a sub-sample of WYC that participated in an intervention to increase physical activity. Both pedometer models have been validated in a number of studies, which collectively concluded the Digiwalker SW-701 and SW-200 were among the most accurate pedometers for assessing steps in adult samples (Crouter et al., 2003; Schneider, Crouter, & Bassett, 2004; Schneider et al., 2003; Tudor-Locke et al., 2002).

### Prevalence of Physical Activity

Due to the small sample of included studies and large variability in methodology and measures, it was not possible to conduct a meta-analysis of physical activity prevalence findings by measurement properties of tools employed. Key activity findings from each included study were grouped by measurement tool properties (e.g., construct, domain, format) to investigate whether the properties of a tool had any bearing on activity findings. No patterns emerged however, between tools of similar attributes. Key activity findings from included studies showed that WYC were less active than women without young children and were less active than they were prior to parenthood (Table 1). Further, greater discrepancies occurred at higher intensities. For example, in a study of 1,113 women 28.6% women with children (aged <17 years) and 44.4% women without children (aged <17 years) engaged in strenuous activity ( $p < 0.01$ ) (Verhoef & Love, 1994). A study that compared a sample of WYC with a sample of men and women participating in a

workplace pedometer study ('workers') found fewer WYC met guidelines for >150 minutes moderate- and vigorous-intensity physical activity than 'workers' (48.7%; 59.5%, respectively;  $p < 0.05$ ). Conversely, WYC spent significantly less time sitting than 'workers', almost 6 hours fewer per day (Brown, Miller, et al., 2003). Significant variations in physical activity levels among WYC were observed across studies, evident through wide standard deviations and variations between studies. Furthermore, WYC in the active and maintenance phases of the Trans-theoretical Model (TTM) of behavior change exceeded current physical activity guidelines, while women in the pre-contemplation, contemplation, and preparation phases showed progressive increases in moderate to very hard physical activity through the model (Fahrenwald & Shangreux, 2006; Fahrenwald & Walker, 2003). Irrespective of these variations, most studies showed that many WYC participated in less than the recommended level of  $\geq 150$  minutes physical activity per week.

## DISCUSSION

This review has provided an overview of the methods employed to measure physical activity in studies of WYC. The current evidence base is dominated by self-reported physical activity behaviors, with questionnaires employed by over 90% of included studies. A lack of motion sensors to measure activity was noted, a finding that was surprising considering their current popularity in this field. Of the studies included in this review, two interviewer-administered instruments provided the most comprehensive assessment of physical activity, the PAR and AWAS; however, many tools assessed leisure-time physical activities only. The PAR and AWAS have undergone validation testing for use in samples of WYC. Due to inconsistencies in measurement methodologies across studies, it was not possible to determine the relation of measurement properties of instruments to the prevalence of physical activity in WYC.

To assess physical activity accurately, an instrument must be appropriate to measure the types of activities routinely performed. WYC had low participation levels in leisure-time physical activity, especially at vigorous-intensities; yet, time spent in household and childcare activities was higher than the rest of the population, and sedentary behavior was lower (Ainsworth et al., 1999; Brown, Miller, et al., 2003; Craig & Bittman, 2008; Scharff et al., 1999). International guidelines recommend physical activities be performed in the context of daily, family, and community activities for leisure, transport, occupation, household, play, games, sports, and planned exercise (World Health Organization, 2010). It is important to consider the contribution that household and childcare activities among WYC may make to overall daily energy expenditure and the potentially consequential reduction of sedentary behaviors. Weller and Corey (1998) examined the relation between physical



activity and mortality among a cohort of Canadian women, specifically the impact of excluding non-leisure energy expenditure on this relationship. The authors reported that the inverse relationship between physical activity and mortality was primarily due to the energy expended in non-leisure activities (household chores), representing 82% of total activity among women. They further emphasized the importance of including assessment of household and occupational activity in measures of physical activity. Moreover, Brown et al. (2001) measured the energy cost of some activities regularly performed by WYC using indirect calorimetry. Their findings showed that many of these tasks (including vacuuming, washing windows, and walking with and without a stroller) were performed at a moderate-intensity (3-6 METs), equivalent to a brisk walk. Consequently, the authors proposed the ideal measure of physical activity among WYC would capture inactivity and physical activity across the spectrum in all domains of activity (leisure, occupational, transport, and household).

Following a comprehensive review of the literature and qualitative research on the physical activity behaviors of WYC, the AWAS was developed to provide a comprehensive tool to capture physical activity across a wide range of health-enhancing activities, including planned and transport activities, household, occupational, and childcare duties (Fjeldsoe, Marshall, & Miller, 2009). As a result, this tool currently provides the most content-relevant assessment of behaviors routinely performed by WYC. Only the planned and transport activity domains reported acceptable validity ( $r_s = 0.22-0.36$ ) (Fjeldsoe, Marshall, & Miller, 2009). It is likely that the weak Spearman correlation coefficients observed when including household, occupational, and childcare domains were due to complexities of behavior recall. Self-report measures misrepresent physical activity among adults (Mackay, Schofield, & Schluter, 2007; Prince et al., 2008), and this effect is most likely to be further evident in populations such as WYC in whom activities are frequently intermittent, simultaneous, and unstructured. It is possible therefore, that data on prevalence of physical activity levels determined from current self-report tools has misclassified WYC as insufficiently active for good health (Brown et al., 2001; Collins, Marshall, & Miller, 2007). While self-report measures do not provide accurate estimates of absolute physical activity, they are useful for measuring a wide range of variables, and importantly, facilitating greater understanding of contexts and patterns of physical activity than objective measures (Sallis & Saelens, 2000).

Despite the widespread use of objective motion sensors in physical activity epidemiology, only two studies assessed activity with pedometers. Both of these studies employed pedometers to assess physical activity change in response to interventions to increase active behaviors. Although some studies of children's physical activity have used accelerometers in parental assessments of activity, parental activity was not an outcome variable and as such these studies were outside the scope of this review (Moore et al.,



1991; Oliver et al., 2010; Taylor et al., 2009). The ability of accelerometers (and some pedometers) to capture temporal movement data objectively throughout a given measurement period allows intermittent and brief periods of activity to be recorded, whereas these periods are likely to be overlooked by self-report tools. Motion sensors providing temporal activity data would, therefore, provide useful evidence of the patterns of the intermittent behavior of WYC, something that is absent in the present literature. Accelerometers do have several limitations. Treatment of accelerometer movement counts to interpret intensity of activities varies significantly amongst studies according to the algorithms employed, consequently making cross-study comparisons difficult (Masse et al., 2005). Frequently accelerometers are hip-mounted and may fail to detect upper body movements, loading, or changes in posture. These variables may be significant to consider in WYC as they may frequently pick up and carry a child for brief or extended periods. The energy cost of this behavior is likely to vary significantly according to the age and weight of the child; however, to the authors' knowledge this is presently unknown. The energy cost of standing, sitting, and lying also varies and neither pedometers nor accelerometers presently enable the differentiation between these behaviors. Recently, inclinometers have been used in physical activity research to measure time spent sitting, standing, and walking (e.g., Lanningham-Foster et al., 2009; Oliver et al., 2010). Inclinometers are worn on the upper thigh and measure tilt angles. These devices have the potential to provide a useful measure of incidental activities and time spent in sedentary pursuits, and further work is needed to validate them among WYC. Inclusion of self-report measures such as time-use diaries in conjunction with temporal motion sensors (accelerometers or inclinometers) may be a novel way of gaining understanding of how WYC move and their patterns of activity.

Limitations of this review included the lack of variability and small sample size of included studies, resulting in the inability to perform a meta-analysis of results by measurement method. Additionally, due to the broad nature of search terms (e.g., women, mother, child, physical activity), it is possible that not all eligible studies were retrieved and included.

It is clear from this review that the current evidence base for the prevalence of physical activity, health outcomes, and moderators of physical activity among WYC is heavily based upon self-reported leisure-time activity. Given well-established benefits of physical activity may be gained from performing physical activity in other domains, future research should endeavor to employ methods that will be sensitive to the unique patterns and contexts of activity of this population. WYC are thought to experience difficulties in categorizing and reporting activity frequency and duration (Collins, Marshall, & Miller, 2007), possibly due to the intermittent and unstructured nature of activities. With this in mind, a tool must first capture the intermittent nature of activities performed by WYC. Secondly, a tool must measure a

broad spectrum of domains and intensities to represent the habitual active living of this population. Third, investigation into the energy cost and muscle strengthening effects of upper body movements associated with carrying children may highlight the need for measurement of these behaviors. Fourth, consideration must be given to measuring sedentary behaviors, as their relative absence in WYC indicates its possible replacement with light-to-moderate-intensity behaviors. Finally, tools must be validated in samples of WYC prior to wide administration. Only once an accurate picture is gathered of the habitual physical activity of WYC, will it be possible to determine whether WYC are in fact a population at risk or whether they are simply considered at risk because their patterns of physical activity differ from what is known of the general population.

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## Demographic variations in discrepancies between objective and subjective measures of physical activity

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### ABSTRACT

**Demographic effects (sex and parenthood status) on the level of association between self-reported and accelerometer assessed physical activity were examined among a large diverse sample of adults. Participants ( $N = 1,249$ , aged 20 - 65 years) wore accelerometers (Actical) for 7 days and completed an interviewer-administered physical activity recall questionnaire (IPAQ-LF) for the same period. Mean daily minutes of moderate physical activity (MPA) and moderate to vigorous physical activity (MVPA) were used in analyses. Linearity between methods was explored by regressing mean minutes of activity and Pearson's correlations were performed. A weak association between IPAQ-LF and Actical minutes of MPA and MVPA per day was shown for the whole sample ( $r_s = 0.216 - 0.260$ ). The magnitude of association varied between males ( $r_s = 0.265 - 0.366$ ) and females ( $r_s = 0.124 - 0.167$ ), although no obvious variations in associations were evident for parenting status. The IPAQ-LF produced substantially greater variations in estimates of physical activity than that recorded by the Actical accelerometer and large discrepancies between methods were observed at an individual level. Self-report tools provide a poor proxy of overall human movement, particularly among females. Inferences made at an individual level from self-reported data, such as intervention efficacy or health outcomes, may have substantial error.**

**Keywords:** Sex; Parent; IPAQ; Accelerometer

### 1. INTRODUCTION

Physical activity is an essential behavioral element in maintaining good health, preventing disease, and pro-

longing longevity [1]. The epidemiology of physical activity considers the association physical activity and inactivity have with chronic diseases, and the mechanisms to prevent and control these diseases. Accurate monitoring of physical activity engagement in free-living populations is central to correctly determining the direction and magnitude of these associations and mechanisms. Conventionally emphasis has been placed on measuring moderate and vigorous physical activities performed in leisure domains, although more recently non-leisure domains (e.g., occupational, transport, household) have featured. In response to growing evidence for the poor health outcomes associated with sedentary behaviors [2,3] and the positive health effects of low-level activity [4,5], a call has been made to incorporate these behaviors in measures of physical activity so that they may be tracked and health outcomes determined [6,7].

In the absence of an agreed-upon criterion for quantifying physical activity many types of measures are applied [8]. Self-report tools (e.g., questionnaires, diaries) are the most widely-used measure of physical activity at a population level. Inherently, these tools rely on participants' ability to accurately recall, quantify, and categorize their physical activity behaviors according to the framework of the self-report tool. Conversely, motion sensors (e.g., accelerometers, some pedometers) can be used to provide an objective assessment of the accumulation of activity movement (commonly lower body movements) throughout a period of time. Accelerometers (e.g., Actigraph, Actical, Caltrac) use piezoelectricity to register acceleration, recording detailed temporal data across the spectrum of activity intensity, including sedentary behaviors and low-level activity.

Many epidemiological studies using self-report measures have shown women to be less active than men [9]. Moreover, some sub-groups of women, such as women with young children (WYC), are thought to be even less active [10]. In part, this may be due differences in the way physical activity is performed and thus measured.



Firstly, planned activities and those performed at vigorous-intensity are most memorable and are therefore more likely to be accurately recalled. Whereas, WYC are known to spend longer durations in total work (paid and unpaid) each day than men with young children (MYC) and women without young children (WNYC), potentially leaving less time for planned leisure [11]. This may also be the case for MYC compared to those without children (MNYC). Additionally, activities of WYC are often sporadic and performed simultaneously with other tasks, for example, carrying a child whilst vacuuming. These types of activities are regularly interrupted with needs of young children that need tending, and difficult to categorize and quantify through self-report [12]. Yet, accelerometers have the ability to record movement regardless of duration, intensity or purpose. It is possible therefore, that systematic differences in the validity of self-report tools may be present across major demographics.

A variety of self-report tools exist, and many studies have examined the validity of self-report tools using accelerometry as the criterion, or objective, measure of physical activity. Previously, discrepancies between objective and subjective measures of physical activity have been shown within adult populations [13-14]; however it is unknown whether these discrepancies vary by certain demographic variables. If this were the case, it would have significant bearing on the selection of measurement tools dependent upon the population being studied. The International Physical Activity Questionnaire (IPAQ) was developed following an international collaboration to develop a standardized self-report measure of physical activity suitable for population-wide assessments of physical activity [15]. The IPAQ long form (IPAQ-LF) requires recall of physical activity engagement at moderate and vigorous intensities for occupational, transport, household, and leisure domains for a 7-day period (either usual or previous).

This study examines the association between activity derived from the IPAQ-LF and concurrent accelerometer derived activity, and, the potential methodological impact on mis-measurement imposed by differences in sex and adults' parenting status. The aims of this study were therefore to: 1) examine the level of association between self-reported and accelerometer assessed physical activity engagement in a large sample of adults, and 2) determine differences in the level of association between measures among men and women with and without young children (aged 0 - 4 years).

## 2. METHODS

Participants were part of the Understanding the Relationship between Activity and Neighborhoods (URBAN)

Study, a multi-centered, stratified, cross-sectional study of associations between physical activity, health, and the built environment in adults and children residing in New Zealand [16]. Objective and self-reported physical activity engagement, neighborhood perceptions, demographics, and body size measures were collected, along with built environment variables. The study contributes to a larger, international collaborative project where similar procedures are utilized across eight countries ([www.openproject.org](http://www.openproject.org)).

### 2.1. Participants

Adults aged 20 to 65 years were recruited randomly from 48 neighborhoods (stratified by high/low walkability, high/low Māori population) across four New Zealand cities during 2008-2010. Trained interviews followed pre-determined walk paths for each neighborhood and approached every *n*th house, according to the neighborhood household sampling rate. One adult from each household was invited to participate. Further details of the neighborhood selection, recruitment methods, and sample power calculations have been described elsewhere [16].

### 2.2. Data Collection

Trained interviewers gained written informed consent and delivered accelerometers and travel/compliance logs during the first home visit. Eight days later, the interviewer visited the home a second time to collect the accelerometer and travel/compliance log, measure participants' height, weight, waist, and hip circumferences, and to administer the study questionnaire.

### 2.3. Measures

A range of measures were utilized in the URBAN study. Those relevant to the current study are outlined below:

#### 2.3.1. Objectively Assessed Physical Activity

Hip-mounted Actical accelerometers (Mini-Mitter, Sunriver, OR) were used to objectively measure participants' physical activity. The units have been shown to be a reliable and valid measure of physical activity in adult populations [17-18]. Accelerometers were prepared to record physical activity and step counts in 30-second epochs. Participants were instructed to wear the unit for all waking hours (excluding water-based activities) for seven consecutive days. Participants self-completed a compliance log of wear-time and activities the participant engaged in whilst not wearing units, for the duration of accelerometer data collection period. The information derived from the log was checked and matched



against accelerometer data.

### 2.3.2. Self-Reported Physical Activity

The International Physical Activity Questionnaire in long form (IPAQ-LF) was administered via interview at the second home visit to capture adults' self-reported physical activity for the previous seven days (the period when the accelerometer was worn). The IPAQ-LF assesses frequency (days), duration (minutes), and intensity (walking, moderate, vigorous) of physical activity engagement across four domains: occupation, transportation, household, and leisure. Moderate physical activity was defined as "those activities that take moderate physical effort and make you breathe somewhat harder than usual"; vigorous physical activity as "those activities that take hard physical effort and make you breathe much harder than normal" [19]. Evidence for the reliability and validity of this tool has been provided for 744 adults across 12 countries [15].

### 2.3.3. Demographics

Participants completed a demographic survey that included: gender, age, ethnicity, marital status, household income, academic qualifications, occupation, dwelling type, and the number and ages of children living in the dwelling.

## 2.4. Data Treatment

### 2.4.1. Self-Reported Physical Activity

According to the IPAQ scoring protocol ([www.ipaq.ki.se/](http://www.ipaq.ki.se/)), minutes of physical activity engagement from the IPAQ-LF were summed across activity domains for each level of intensity (walking, moderate, and vigorous). Mean daily minutes of moderate (sum of walking and moderate, MPA), vigorous (VPA), and sum of MPA and VPA (MVPA) activity engagement were calculated to minimize the effect of missing days of accelerometer data.

### 2.4.2. Objectively Assessed Physical Activity

Accelerometer data were downloaded using Actical® version 2.04 (Mini-Mitter Co., Inc., Bend, OR, USA). Thresholds for MPA and VPA were generated by the Actical software and were based on MET-value based cutpoints. Data were prepared for analysis using SAS (version 9.1, SAS Institute Inc., Cary, NC, USA) and Microsoft Excel. Bouts of 60 or more consecutive minutes of zero counts were considered non-wear-time and extracted prior to analysis [20]. Wear-time criteria for inclusion were defined as having five or more days of 10 or more hours of wear-time per day. Mean daily minutes of MPA, VPA, and MVPA activity were used in all ana-

lyses to ensure comparability across the sample. Mean values for individuals were calculated using the number of days of accelerometer wear that met wear-time criteria.

## 2.5. Statistical Analyses

All analyses were undertaken using SPSS (version 18) and statistical significance was set at  $\alpha = 0.05$ . Shapiro-Wilk's test of normality was conducted for both physical activity measures, and non-normal distributions were log transformed to achieve normality. Means and standard deviations were used to describe both methods of measurement for the whole sample and each demographic (WYC, women with young children [children aged 0 - 4 years]; MYC, men with young children; WNYC, women with no young children; MNYC, men with no young children).

Commonly, correlation coefficients are used as a single score of validity between measures however it is appropriate to explore associations with a broader view. Firstly, a test of the differences between measurement means allows quantitative assessment of whether methods are significantly different from each other. Secondly, a scatter plot of the two measures with the line of identity provides visual assessment of linearity and systematic or random bias in the relationship between measures. The correlation coefficient can then be calculated as a summary of the overall scatter between measures, indicating the strength of the linear relationship [21]. Therefore, paired *t* tests were used to compare means between methods, and linearity was explored by regressing mean minutes of activity at each intensity derived using the IPAQ-LF against mean minutes of Actical. Evaluation of linear relationships between Actical and IPAQ-LF using Pearson's correlation were performed. Results are presented for the whole sample and comparisons made between demographic groups (WYC, MYC, WNYC, MNYC).

## 3. RESULTS

### 3.1. Participants

A total of 2013 adults aged 20 to 65 years participated in the URBAN study between April 2008 and September 2010. Participants with missing demographic ( $n = 4$ ) or IPAQ-LF ( $n = 5$ ) data were excluded, as were participants who did not meet criteria for accelerometer wear-time ( $n = 731$ ). Outliers in IPAQ-LF data were calculated using interquartile range (IQR) computation, where any value more than 3 IQR above the third quartile were considered a problematic outlier ( $n = 24$ ). Therefore data from 1249 participants were included in



these analyses (Table 1).

### 3.2. Moderate Physical Activity

Descriptive statistics, presented in Table 1, indicate that the IPAQ-LF reported significantly higher means of MPA engagement than the Actical ( $t = 2.104, p = 0.036$ ). Additionally, standard deviations of the means were substantially greater for the IPAQ-LF indicating greater variance in self-reported activity levels. The scatter plot demonstrated a weak relationship between measures, as can be observed in Figure 1; whilst the regression line passes the line of identity ( $\log_{ny} = \log_{nx}$ ) near the means for both measures, the scatter indicates significant random bias. Further, evaluation of the linear relationship between methods indicated a weak association ( $r = 0.216, p = 0.000$ ).

All demographic groups reported higher mean estimates of MPA by IPAQ-LF than measured by Actical, however these differences were only significant in MNYC ( $t = 2.680, p = 0.008$ ). Weak associations between methods were found for both WYC and WNYC ( $r = 0.124, p = 0.164$  and  $r = 0.130, p = 0.002$  respectively), while for MYC and MNYC a linear (albeit weak-moderate) relationship was found between measures ( $r = 0.265, p = 0.015$  and  $r = 0.331, p < 0.001$ , respectively).

### 3.3. Moderate-to-Vigorous Physical Activity

Actical derived MVPA increased marginally from MPA whereas IPAQ-LF MVPA values increased disproportionately indicating much greater vigorous activity via self-report compared with objective measurement

(Table 1). As was observed with MPA, paired  $t$  test results revealed significant differences between method means ( $t = -3.385, p = 0.001$ ) and weak association between methods ( $r = 0.260, p = 0.000$ ). Scatter plots continued to show significant random bias in self-report (Figure 2).

All demographic groups self-reported more MVPA than recorded by accelerometer, and both male groups self-reported substantially greater VPA than either female group. Significant differences were observed between methods for MVPA means for MYC, and WNYC, but not for WYC or MNYC. Methods were moderately correlated for MVPA for both male groups ( $r = 0.337, p = 0.002$  and  $r = 0.366, p < 0.001$ , respectively) yet both female groups showed similarly weak associations ( $r =$

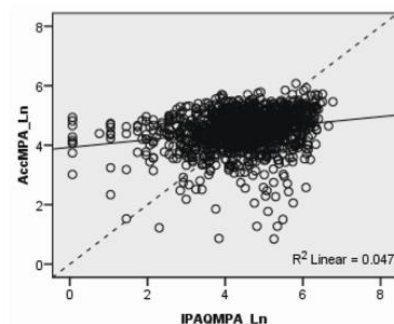


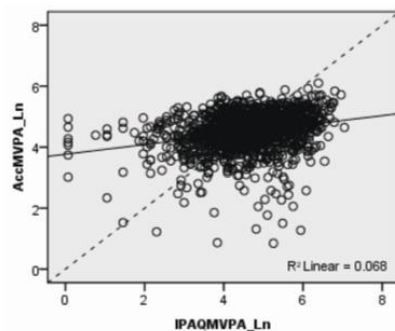
Figure 1. Association between self-report and accelerometer derived MPA for the whole sample. Note: dashed line represents line of identity; solid line represents linear regression line.

Table 1. Participant characteristics and descriptive statistics of IPAQ-LF and Actical measures.

8	Total sample N = 1249	WYC N = 128	MYC N = 84	WNYC N = 588	MNYC N = 449
Age					
18 - 25	121	10	8	50	53
26 - 35	254	52	32	93	77
36 - 45	353	55	34	161	103
46 - 55	301	6	9	175	111
56 - 65	213	4	1	106	102
Missing	7	1	0	3	3
Height cm*	169.32 ± 9.83	164.80 ± 6.96	177.99 ± 6.12	163.55 ± 7.70	176.53 ± 7.41
Weight kg*	76.51 ± 17.24	72.31 ± 18.42	85.67 ± 13.53	70.16 ± 15.62	84.15 ± 15.68
BMI kg/m <sup>2</sup> *	26.70 ± 8.26	26.49 ± 5.85	26.90 ± 3.81	26.52 ± 10.98	26.95 ± 4.51
Moderate physical activity					
Actical (min·day <sup>-1</sup> )*	106.51 ± 57.61	104.79 ± 56.79	114.31 ± 56.79	101.31 ± 53.60	112.36 ± 62.33
IPAQ-LF (min·day <sup>-1</sup> )*	134.91 ± 128.35	132.05 ± 111.40	180.65 ± 185.37	125.36 ± 137.90	139.68 ± 137.90
Correlation	$R = 0.216, p < 0.001$	$R = 0.124, p = 0.164$	$R = 0.265, p = 0.015$	$R = 0.130, p = 0.002$	$R = 0.331, p < 0.001$
T-test	$t = 2.104, p = 0.036$	$t = -0.205, p = 0.838$	$t = -0.111, p = 0.912$	$t = 0.893, p = 0.372$	$t = 2.680, p = 0.008$
Moderate-vigorous physical activity					
Actical (min·day <sup>-1</sup> )*	106.75 ± 57.91	104.93 ± 56.86	114.52 ± 57.04	101.48 ± 53.77	112.72 ± 62.85
IPAQ-LF (min·day <sup>-1</sup> )*	160.66 ± 157.98	140.21 ± 115.72	227.24 ± 234.39	140.56 ± 122.96	180.36 ± 184.03
Correlation	$R = 0.260, p = 0.000$	$R = 0.161, p = 0.069$	$R = 0.337, p = 0.002$	$R = 0.167, p = 0.000$	$R = 0.366, p = 0.000$
T-test	$t = -3.385, p = 0.001$	$t = -1.144, p = 0.255$	$t = -2.533, p = 0.013$	$t = -2.060, p = 0.040$	$t = -1.596, p = 0.111$

\*Values are presented as Mean ± Standard Deviation.





**Figure 2.** Association between self-report and accelerometer derived MVPA for the whole sample. Note: dashed line represents line of identity; solid line represents linear regression line.

0.161,  $p = 0.069$  and  $r = 0.167$ ,  $p < 0.001$ , respectively).

#### 4. DISCUSSION

This study investigated the demographic effects of sex and parenthood status on associations between a self-report tool (IPAQ-LF) and objective method (Actical accelerometry) for describing MPA and MVPA in adults. A weak linear relationship between IPAQ-LF and Actical minutes of MPA and MVPA per day was shown and the magnitude of association varied between men and women; no obvious variations in associations were evident for parenting status.

It is evident from the regression plots that the IPAQ-LF produces greater variation in estimates of physical activity variables than recorded by the Actical accelerometer, which is reflected by the weak associations found between measures across all demographic groups. Importantly, at a population level the method means were similar however substantial discrepancies between measures occurred at an individual level. This indicates that inferences made at an individual level, such as intervention efficacy or health outcomes may have substantial error; the utility of self-report tools for such a purpose is therefore questionable for all demographic groups, however this may be more so among women. Previous IPAQ-LF validation studies have reported moderate associations with accelerometry ( $r = 0.30 - 0.33$ ) [15,22] and doubly labeled water ( $r = 0.31$ ) [23] for describing MVPA in adults. None of these studies reported demographic-specific associations, although similar associations were reported across 12 countries, including developing countries [15]. In the validation study of a self-report tool developed for use among WYC incorporating a variety of domains, comparably weak associations of self-reported MVPA with acceler-

ometer-derived MVPA were reported ( $r_s = 0.13$ ) [24]. The same study reported improved associations when considering MVPA from planned and transport domains of activity only ( $r_s = 0.28$ ).

Moderate associations between self-reported and accelerometer-derived physical activity are typical [13-25]. Because of their widespread availability, low cost, and ease of use, self-report tools continue to be employed despite their well-documented shortcomings [15]. In particular, self-report tools are cognitively challenging; they require participants to recall, estimate, and classify physical activity engagement, usually over a 7 day period. A study that probed respondents for clarification of self-reported responses found 74% over-reported, 10% under-reported, and 16% reported total activity accurately [26]. Social desirability bias may also lead to over-inflated estimates of physical activity behavior. Further, self-report tools are biased to certain patterns of activity; planned activities and those of vigorous-intensity are more accurately and reliably recalled than low-level intermittent behaviors [15,26]. The latter methodological flaw potentially misses vast quantities of health-enhancing activity, especially in those who are unable or lack opportunity to participate in vigorous-intensity activity. Efforts have been made to rectify this somewhat by attempting to capture time spent in occupation and domestic physical activities. Arguably however, physical activity performed in these domains is often low-level and intermittent, therefore difficult to recall accurately. A common feature of self-report tools is also to exclude activity bouts of <10 minutes. Whilst this may improve the reliability in recalling behavior it systematically excludes activities regularly promoted as health enhancing, such as using stairs instead of the elevator, parking further away and walking the extra distance, and many domestic and yard activities of moderate-intensity. Algorithms to extract minimum bouts of activity recorded by accelerometers (e.g.,  $\geq 10$  minutes, allowing 1 - 2 minutes interruption within each bout) have been promoted and utilized in some studies in order to provide comparability with many self-report tools [27-29]. Whilst this method may produce greater convergence between measures, this may simply be case of biasing the objective measure to systematically miss more actual activity. Such methods were not used in this study because of its inherent limitations. Firstly, activity which most health professionals would regard as "health-related" is often not conducted in one continuous bout, even after allowing for a 1 - 2 minute interruption, and may fluctuate between light-intensity and vigorous intensity, as is common place in many sports and recreational activities. Further, this approach may exclude significant contributions that short bouts of activity make to



overall daily physical activity.

It is likely that patterns of activity may contribute to the sex effects observed in this study. Particularly, women (both with and without young children) may be more likely to perform low-level intermittent activity than engage in planned bouts of vigorous-intensity activity, potentially producing greater variability in reporting. It appears that sex has a greater effect on self-report accuracy than parent status; this may be due to the presence of confounding factors such as parental employment, presence of older children, socioeconomic status, and marital status. The IPAQ battery of questionnaires were developed in an attempt to provide a standardized self-report tool suitable for population estimates of the prevalence of physical activity so that comparisons between countries may be made [15]. Whilst there is some merit in this purpose at a population level, the application of self-report tools to determine health outcomes of physical activity behavior is inappropriate. The present study has concurred with previous research demonstrating a weak-to-moderate association between self-reported and accelerometer derived behavior [13-14]. Importantly however, this research further shows that the ability of self-report tools to capture overall activity is particularly weak among women, probably due to lower levels of planned moderate- to vigorous-intensity activity. With greater emphasis now being placed on measuring physical activity across the spectrum it is important that measurement tools are capable of doing so accurately.

The strengths of this study include its large heterogeneous sample with a spread of demographics providing adequate variations in physical activity for exploring associations across a full range of activity levels. It appears that the sample in this study were highly active, although this is an acknowledged outcome of the IPAQ-LF given the number of domains considered [15]. A limitation of the study is that it was not methodologically designed for measurement tool validation, reflected by the high proportion of participants that were excluded due to inadequate accelerometer wear-time. This study demonstrates substantial discrepancies between self-report tools (specifically the IPAQ-LF) and accelerometer derived physical activity. Findings indicate that self-report tools provide a poor proxy of human movement, especially among women. Careful consideration must be given to the patterns of activity in the intended study population and the purpose of measurement.

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