

Understanding Children's Independent Mobility

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List of Abbreviations

Abbreviation	Definition
AUTEC	Auckland University of Technology Ethics Committee
BIA	Bioelectrical impedance analysis
BMI	Body mass index
BP	Blood pressure
CAPI	Computer-assisted personal interview
CVD	Cardiovascular disease
GIS	Geographic information systems
GPS	Global positioning system
HDL	High density lipoprotein
IM	Independent mobility
IMB Area	Independent mobility boundary area
IMB Distance	Independent mobility boundary distance
IMD Area	Independent mobility destination area
IMD Distance	Independent mobility destination distance
IQR	Interquartile range
MetS	Metabolic syndrome
MVPA	Moderate-to-vigorous physical activity
OECD	Organisation for Economic Cooperation and Development
PA	Physical activity
SPSS	Statistical package for the social sciences
WHtR	Waist to height ratio
VERITAS	Visualisation and Evaluation of Route Itineraries, Travel Destinations, and Activity Spaces

Nomenclature

Term/Symbol	Definition
CI	Confidence interval
kg	Kilogram
km	Kilometre
km ²	Kilometre squared
n	Number of cases in a subsample
N	Total number of cases
OR	Odds ratio
%	Percentage
%BF	Body fat percentage
±	plus–minus
<i>p</i>	p-value, statistical significance
<i>R</i> ²	R-squared
<i>SD</i>	standard deviation

List of Publications Arising from Doctoral Thesis

Peer-reviewed Journal Publications

Papers published:

Bhosale, J., Duncan, S., Schofield, G., Page, A., & Cooper, A. (2015). A pilot study exploring the measurement of intergenerational differences in independent mobility. *Transport and Health*, 51, 522–528. doi:10.1016/j.jth.2015.08.004

Papers under review:

Bhosale, J., Duncan, S., Stewart, T., Chaix, B., Kestens, Y., & Schofield, G., (under review). Measuring children's independent mobility: Comparing interactive mapping with destination access and license to roam. *Journal of Children's Geographies*.

Bhosale, J., Duncan, S., & Schofield, G., (under review). Intergenerational change in children's independent mobility and active transport in New Zealand children and parents. *Health and Place*.

Papers in preparation for submission:

Bhosale, J., Duncan, S., & Schofield, G., (in preparation for submission). Associations between children's independent mobility, physical activity and sedentary behaviour.

Bhosale, J., Duncan, S., & Schofield, G., (in preparation for submission). Associations between children's independent mobility and body composition.

Peer-reviewed Conference Presentations

Bhosale, J., Duncan, S., & Schofield, G. (2011). *Free Range Kids: Intergenerational differences in independent mobility*. Research 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

Childhood is a critical developmental period; patterns of physical activity established during this time are likely to track into adolescence and adulthood. Children who are regularly physically active benefit from greater bone mineral density, enhanced motor skills, maintenance of a normal weight status, and risk reduction for a myriad of non-communicable diseases. Insufficient physical activity in children has stimulated widespread investigation into behaviours that can promote or inhibit activity during this important life stage. The ability to play, roam and move unsupervised (independent mobility), is a fundamental behaviour, which provides natural opportunities for habitual physical activity. A proposed decline in children's independent mobility (IM) has recently gained attention as a likely and important contributor for low activity levels in children. However, comprehensive understanding of this behaviour is presently limited by the absence of standardised measurement techniques. The overarching aim of this thesis was to develop innovative measures of IM to explore intergenerational differences in IM and investigate the associations between IM and physical activity in 10-13-year-old children.

An initial pilot study was conducted in Auckland, New Zealand and three different measures of children's IM were explored with three generations of directly related participants (Chapter 3). Self-reported independent parental licences to travel without an adult (IM Licence) and independent roaming allowances to certain locations (summed to form an index; IM Index) were collected for 45 participants. The third measure was an interactive map to record the self-reported maximum roaming distance from home residence (IM Maximum). Substantial intergenerational differences were observed across all IM measures. Mean IM Maximum travelled by grandparents was 7810m (SD = 7064), which declined to 5335m (SD = 4940) for parents and further reduced to 2673m (SD = 1929) for children. Similarly, IM Index declined from grandparents to parents and even further in children (2.54, SD = 0.70; 2.28, SD = 0.44; 1.49, SD = 0.28; respectively). Differences for both IM Index and IM Maximum were only statistically significant between parents and children, indicating the degree to which this behaviour has recently changed. In regard to IM Licences, only one child was permitted the same completely unrestricted licence to roam and travel freely in the neighbourhood that their parents and grandparents experienced. These findings provided novel evidence of the direct intergenerational change in children's IM and showed the potential benefits of using an online mapping application.

The IM measures explored in Chapter 3 were further refined in Chapter 4. An innovative mapping application (VERITAS-IM), which captures geospatial IM data, was customised for use in children. The main objective of this study was to compare VERITAS-IM measures with IM Index and IM Licence. Significant linear trends were revealed between IM Index and the VERITAS-derived measures: IM Boundary Area (IMB Area) and Distance (IMB Distance). For every one unit increase in IM Index, IMB Area increased by nearly 4 km², and IMB Distance increased by 1 km. In regard to parental licences, those who had parental licences in all contexts, except to go out after dark (travel to and from school, cross and cycle main roads, use public transport), had significant higher IMB Area (ranging from 1.46-2.45 km²) and IMB Distance (ranging from 1.68-2.15 km) compared to those who were not permitted these licences (IMB Area: 0.12-0.43 km² and IMB Distance: 0.57-1.36 km). These results provide the first quantitative evidence that children with greater parental freedoms experience a significant and meaningful increase in their perceived IM area.

Historical and current IM in 500 New Zealand children and parents were characterised through IM Index, IM Licence and active travel modes (Chapter 5). Significant generational decreases were observed across all measures. Compared to children today, parents were twice as likely to be granted freedom to travel to school, cross main roads and go out after dark unsupervised. Similarly, parents were four times as likely to be allowed to cycle main roads unsupervised, reflected in an absolute decrease from 76.0%-43.2%. IM Index also declined significantly between parents and children in both males (2.05-1.53) and females (1.77-1.40). A drastic decline in children using active modes of transport was observed, with parents eleven times more likely to use active modes of transportation; only 49.0% of children used active transportation to school and 56.9% from school compared to 91.8% and 93.2% respectively for parents. Overall, each of these measures highlight the significant changes in IM and active transportation in just one generation.

To understand the potential impact of declining IM on physical health outcomes, geographically defined VERITAS-IM measures developed in Chapter 4 were compared with objectively measured physical activity and sedentary time (Chapter 6), as well as body composition measures (Chapter 7). Children with high IMB Distance had significantly higher moderate-to-vigorous physical activity (MVPA) compared to those with restricted freedoms (15.4 minutes).

Conversely, those with low IMB Area and Distance had significantly higher sedentary time per day than those with high IM (54.5 minutes and 36.1 minutes, respectively). No significant associations were found between children's IM and body mass index, body fat percentage, or waist-to-height ratio. While the reduction in children's ability to play and roam independently in the neighbourhood appears to significantly contribute to low levels of activity, it is possible that IM does not mediate the complex causal pathway of childhood obesity in isolation.

The development of novel IM measurement techniques, including an innovative online mapping application, provides a unique contribution to IM research. In particular, the VERITAS application offers a standardised measurement technique to quantify children's independent roaming distances and areas, which is currently absent. Furthermore, the understanding of intergenerational change in children's IM and novel quantifiable evidence of the relationship between current autonomous roaming, physical activity and obesity in children also represents a substantial original contribution to the body of knowledge in IM. The work presented in this thesis has significant implications for the current measurement practice of children's IM and it is apparent ongoing work is needed to investigate effective strategies to support children's independent roaming in the local sphere.

Chapter 1. Introduction

Background

Context

Physical activity is fundamental for optimal health and wellbeing across the lifespan. Predominantly defined as any bodily movement produced by skeletal muscle which results in energy expenditure,^[1] physical activity has immediate benefits on muscular strength, cardiovascular fitness, psychological health and maintenance of a normal body weight^[2,3]. Specific benefits for youth who are physically active include improved bone health, enhanced motor skill development and a decreased risk of anxiety or depressive symptoms.^[4] Conversely, low levels of physical activity are associated with an increased risk of several non-communicable diseases of which cardiovascular disease, diabetes, cancer and chronic respiratory diseases pose the biggest threat to global mortality.^[5]

As a species humans have evolved from the basic need to survive, in which daily movement was not an option, to a modern environment shaped to eliminate physical exertion. It is now possible to virtually expend no or very little energy throughout a day, and epidemiological evidence indicates that this is indeed the case for many adults and children. Current global data suggests that 23% of all adults and 80% of adolescents do not meet recommended guidelines.^[5] Outcomes from a recent Global Summit indicated that from 39 countries, only 23% of 11-year-olds achieved 60 minutes of moderate-to-vigorous activity a day.^[6] Equally concerning are the high rates of physical inactivity in children worldwide. At the time of this thesis a very recent global study indicated that children from 12 developed and developing countries spend 8.6 hours a day sedentary and 54.2% of children fail to meet screen time guidelines of less than two hours a day.^[7]

Investigation into behaviours that contribute to overall activity levels in children is imperative to help establish lifelong movement habits. There is widespread evidence that activity patterns established in childhood have a tendency to track into adolescence and adulthood^[8-11]. In an environment which strives to eliminate movement, it is probably easier to cultivate a social environment where physical activity is accumulated incidentally through unstructured and unorganised play, roaming and travel. There is substantial social commentary about the decrease

in these and how they affect health, yet very little objective research has examined how they have changed.

Independent Mobility

The ability to play, roam and move unsupervised (independent mobility), is a fundamental active behaviour, crucial to children's physical and psycho-social development.^[12-14] Independent mobility (IM) provides children with natural opportunities to accumulate habitual physical activity,^[15-17] develop social skills^[18,19] and improve cognitive ability.^[12,20] Children who experience greater autonomy in their neighbourhood are also more likely to take risks, which is necessary to develop resilience and self-confidence in preparation for the adult world.^[21,22] Despite the benefits, it is generally perceived that children's IM has reduced from previous generations. Self-reported declines in children's IM licences (permission to go to certain places unsupervised) have been reported in a number of developed countries including England,^[23] Australia,^[24] and Finland.^[25] However, the extent of this decline remains largely unknown, and no data currently exists on the change in this behaviour in New Zealand. Consequently, the long-term implications of the decline in IM on children's health and development are yet to be understood.

The Wider Environment

A number of key social and environmental changes have been postulated to reduce children's opportunities for autonomous roaming. The urban space has previously been a place safe for children to play.^[26] Developments in the built environment have reduced green areas and increased urban sprawl, making travelling times longer and streets more dangerous with increased numbers of speeding vehicles on the roads.^[27,28] Parental perceptions of the risk from both traffic-related accidents and 'stranger danger' have been regularly reported to restrict children's freedoms heavily,^[29-33] further adding to the increase in traffic density by chauffeuring children to and from school and a myriad of structured activities.^[34,35] While parents believe they are providing the best for their children, it is likely that there is a discourse between their perceptions and the independence children desire.^[36] The social norm that children are not capable of being their own agents has further contributed to their views being disregarded in urban planning and policy decisions.^[37]

The complex nature of children's IM, influenced by the interaction of many individual, community and government level factors, calls for a multilevel approach.^[13] The core foundation of socio-ecological frameworks is one in which both the environment and the individual work in unison to create sustainable change; one is not as nearly as effective without the other.^[38] Methodology of empirical studies needs to reflect this approach in order for comprehensive data to be captured with which to form effective multilevel interventions. The field of children's IM has received growing attention, especially following Hillman and colleagues' landmark study in 1990;^[23] however, measurement techniques have not yet advanced.^[39] Measurement of physical activity, on the other hand, has evolved substantially and objective measurements with accelerometers are common practice.^[40,41] The emergence of online technology, which has in part driven trends of declining IM and increased opportunities for sedentary based activities,^[42] may inadvertently provide an aperture for the development of standardised IM measurement techniques. It is probable that there is a relationship between children's declining IM and low levels of activity present in youth today, and emerging research provides supportive evidence for this association.^[15,43-45] However, prior to investigating this line of enquiry further, robust measures of IM need to be developed.

Thesis Rationale

Statement of the Problem

There is an urgent need for evidence-based strategies to increase physical activity and decrease sedentary behaviour in children. It is possible that children with restricted IM engage in less physical activity than those with increased freedom for spatial mobility. However, there are a number of inherent gaps in IM research, limiting our understanding of this fundamental behaviour and how it may benefit children's health and development.

Firstly, an elementary issue is the absence of a standardised measure of children's IM.^[39] Accurate, reliable measurement of how children play and roam unsupervised is crucial for collecting valid data, identifying populations at risk of low mobility, and to gain an in-depth understanding of the associations that inhibit or promote IM. It has been suggested that a mixed methods approach may offer a robust means to capture the complex nature of children's IM.^[39] New technology has given rise to the development of interactive mapping as a potentially viable

mixed methods approach.^[46,47] The use of this approach is very much in its infancy and applications which are customised for children remain scarce. Furthermore, it remains unknown how (or if) this new methodology relates to more traditional measures of IM. Addressing the measurement of children's IM is a crucial starting point for the research field.

There is some international research to suggest that children's IM has decreased from earlier generations.^[23,24,30,48,49] However, an investigation measuring this potential change in children's IM using directly related participants has yet to be conducted. Evidence of the precise intergenerational change in IM is crucial for understanding the magnitude of this issue for children to provide a clear starting point to form new strategies and public policies. In addition, while there have been a handful of studies exploring children's autonomous roaming in New Zealand, research determining the decline in IM for youth has not been conducted.

Crucially, there is a dearth of knowledge surrounding the benefits of IM on children's wellbeing, especially in relation to risk factors for chronic disease. The presence of biomarkers for lifestyle-related disease in children including obesity,^[50] hypertension,^[51,52] and metabolic syndrome^[53,54] demands urgent attention in this area. A small number of investigations have explored possible associations between IM and physical activity;^[15,43-45,55] however, they have been limited by methodological difficulties and more robust evidence is required for these relationships to be empirically established. In addition, a paucity of research exists between sedentary behaviour and children's IM, despite being recognised as a risk factor independent of physical activity.^[56] Moreover, physical activity is recognised as a key strategy in the prevention and reduction of childhood obesity;^[50] however, there is an absence of research to determine if IM can influence children's body composition. At present, research of this nature has not yet been conducted in New Zealand and this evidence will provide an important contribution to the national body of knowledge in children's health.

Statement of the Purpose

The overall aim of this thesis was to provide a comprehensive understanding of children's IM by developing and testing robust measures of IM to explore intergenerational differences in IM and to determine associations between children's IM, physical activity and other health biomarkers.

The specific objectives of this research were to:

1. Review and critique existing research that has examined children's independent mobility with reference to the wider epidemiological field (Chapter 2).
2. To develop an accurate and feasible method of measuring children's IM across different generations:
 - a. To assess the feasibility and acceptability of measuring IM in children, parents and grandparents (Chapter 3).
 - b. To compare geographically defined IM measures with traditional IM indicators (Chapter 4).
3. To characterise current and historical independent mobility in a large sample of New Zealand children and parents (Chapter 5).
4. To investigate the associations among children's independent mobility and key risk factors for chronic disease:
 - a. To compare children's IM with objectively measured physical activity and sedentary behaviour (Chapter 6).
 - b. To compare children's IM with a number of key body composition measures (Chapter 7).

Significance of the Research

There is considerable evidence to indicate a drastic reduction in physical activity between childhood and adolescence.^[57,58] Investigations into possible behaviours that can be established and maintained to mediate this decline are in demand. IM is crucial for children's physical and psycho-social development;^[12,14,17] however, there are a number of inherent gaps in knowledge preventing a comprehensive understanding of this fundamental behaviour. This thesis aims to address these gaps, providing a number of important and novel contributions to the body of literature in New Zealand and the international platform.

Accurate measurement of children's IM is imperative to understand the extent to which this behaviour has declined and the implications such restrictions on children's spatial mobility have on their immediate and long-term health. The measures of children's IM developed for this study are innovative and novel. The creation of an interactive online mapping application for children joins a very scarce body of research internationally and is the first of its kind in New Zealand. This application provides a valuable contribution to the research field and potentially offers a standardised measurement option which is currently absent. A further research gap is understanding how measures of children's IM derived from an online mapping application compare with more traditional IM measurement techniques. This thesis provides essential founding evidence to address this research gap.

Accurate baseline data of children's current and historical IM is fundamental to understanding how this behaviour has changed. This is the first study worldwide to assess change in children's IM with directly related participants. The extent to which children's ability to play and roam in New Zealand has changed from earlier generations remains unknown. These findings will provide a significant contribution to the global field of IM research, enabling a greater understanding of the extent to which children's IM has declined.

Children's low levels of activity and rising time spent sedentary is a major public health concern.^[6,7] Current understanding of the association between children's IM and physical activity is limited and impaired by an absence of standardised measurements. This research will provide novel quantifiable evidence of the current roaming distances and areas of children in New Zealand and determine the contribution this can make to daily activity levels. Furthermore, this thesis will

address whether habitual movement through IM is associated with childhood obesity and other key body composition measures, for which there is a paucity of research. Evidence of these correlations will provide a significant and novel contribution to the field of children's IM and wider epidemiological research in children.

The central focus of this thesis is to provide an unprecedented understanding of children's IM with robust methodology. It is envisaged that this novel research will assist in the development of strategies to enable New Zealand children to accumulate more habitual physical activity, experience greater independence in their everyday lives and help prevent the onset of chronic illness.

Study Delimitations

Parameters specific to this body of work are as follows:

1. The age range of children involved were restricted to those in intermediate school (10-13 years old from year of birth); exact date of birth could not be determined from an ethical standpoint. Caution should be strongly considered when making generalisations about youth.
2. The data collected is cross-sectional; subsequently, no causality can be inferred.
3. Accelerometers are a valid technique to quantify daily movement in children; however, they do not account for water-based activities, cannot measure upper body movement, and types of sedentary behaviour cannot be determined.^[41]
4. Measures of IM developed and used in Chapters 3-7 are in essence self-reported. It is possible that participants encountered recall difficulties which may have resulted in desirability bias.

Thesis Overview

Thesis Organisation

This thesis is presented as a successive progression of studies arranged in a series of eight chapters (Figure 1-1). The first chapter provides an introduction to the topic and overall rationale for the research. The second chapter establishes the context of the research with a comprehensive literature review. The third chapter comprises an exploratory study for measuring IM across three generations with an online mapping technique. This new methodology is further refined and compared to traditional indicators of IM in Chapter four. The fifth chapter characterises current and historical IM in a large population sample of New Zealand children and adults. Chapters 6 and 7 narrow down to investigate specifically the associations between IM and a range of physical health indicators in children. Chapters 3 to 7 have been prepared as separate papers for publication in peer-reviewed journals; therefore, some repetition of information occurs. Each chapter is connected with a preface which also assists to progress the studies sequentially. 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 scientific and wider communities while noting the limitations of the research. Supplementary information not provided in the thesis chapters has been included as Appendices.

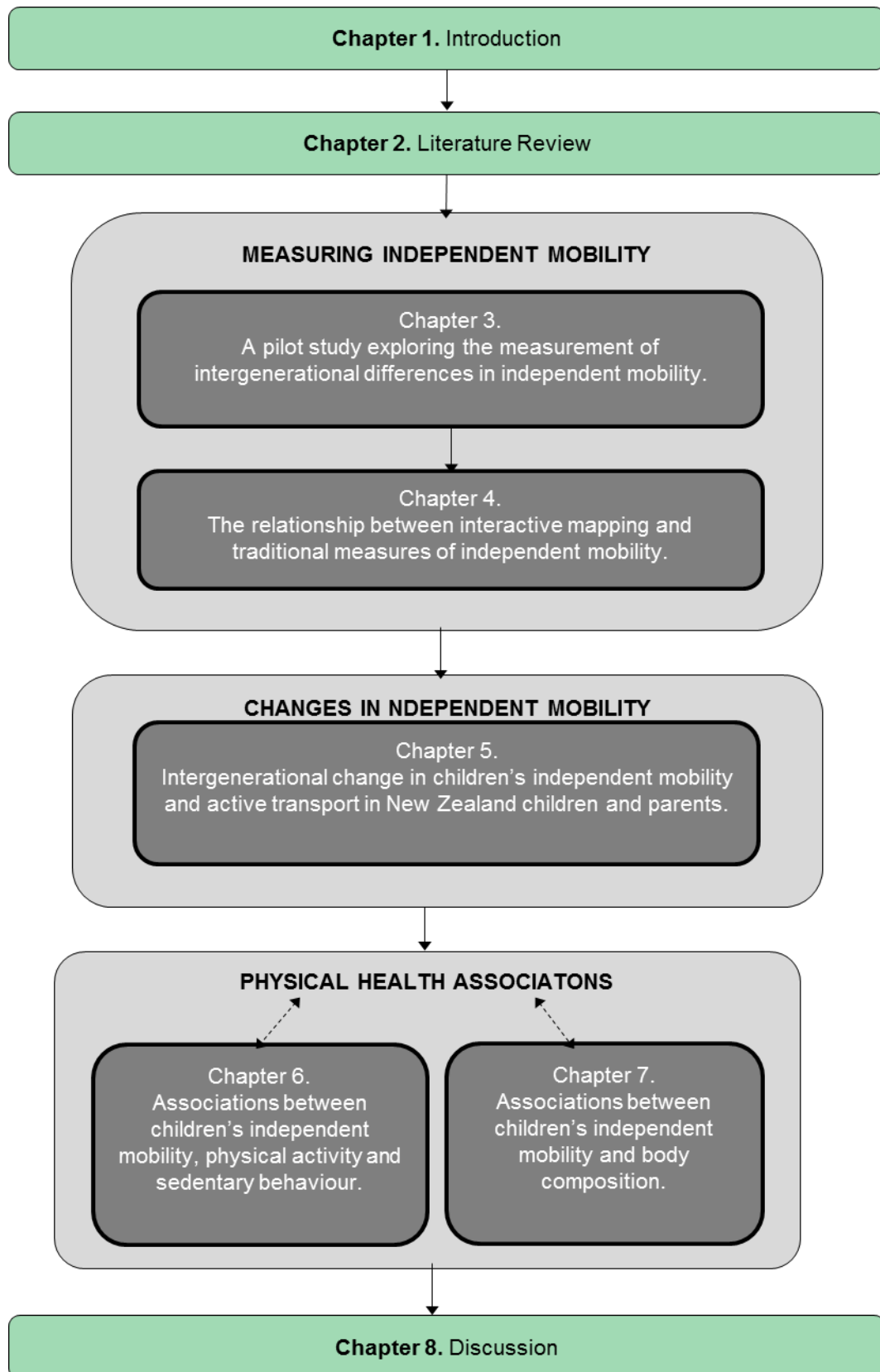


Figure 1-1. Thesis structure

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: A pilot study exploring the measurement of intergenerational differences in independent mobility.

Julie Bhosale85%

Scott Duncan.....10%

Grant Schofield.....5%

Chapter 4: The relationship between interactive mapping and traditional measures of independent mobility.

Julie Bhosale80%

Scott Duncan.....10%

Tom Stewart5%

Grant Schofield.....5%

Chapter 5: Intergenerational change in children's independent mobility and active transport in New Zealand children and parents.

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Chapter 6: Associations between children's independent mobility, physical activity and sedentary behaviour.

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Chapter 7: Associations between children's independent mobility and body composition.

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Chapter 2. Literature Review

Preface

The paediatric population stands to gain monumental benefits from achieving daily recommended levels of physical activity. Pre-adolescence is an important developmental period and an opportune time to catch potential declines in habitual physical activity. Emerging research indicates the periods after school and during the weekend are important times to target with physical activity interventions. These particular periods of time are when children would have the greatest opportunity to roam unsupervised in their neighbourhood (independent mobility). It has been proposed that children's independent mobility (IM) has declined from earlier generations due to a number of environmental and psycho-social influences. New research has also surfaced indicating that children who experience severe restriction on their spatial movement in the neighbourhood suffer from lower levels of physical activity than children with increased freedom. However, this research has been conducted without consistency between the definition and measurement of IM. A comprehensive understanding of IM and the current gaps in research in this area will provide the foundation for future research. The purpose of this review was therefore to evaluate the current state of knowledge of IM with respect to children's physical activity and indicate current deficits in the evidence.

Physical Activity in Children

Physical activity is routinely defined as any movement produced by skeletal muscles resulting in energy expenditure.^[1] Daily accumulation of physical activity for children comes from movement including recreational activity, active transport modes (walking and cycling), play, sports and other structured activities.^[59] The activity intensity spectrum is divided into three levels: light, moderate and vigorous activity, in addition to sedentary behaviour. Moderate intensity is classified as the equivalent of a brisk walk, and vigorous activity is activities that will make you 'huff and puff'.^[59] There is now substantial evidence to show the beneficial effects from all intensities of physical activity on children's immediate health and for offsetting the risk of a number of non-communicable diseases. Some of the benefits of physical activity are described below.

Physical Activity Benefits

Motor Skill Development and Coordination

The development of movement patterns and skills is a continual learning process. Early exploratory activities enable children to develop motor skills which are fundamental to movement.^[60] As children grow, more advanced motor skills such as throwing, catching and jumping are developed based on environmental stimulation.^[21] It is likely that children who do not engage in sufficient physical activity can miss out on the development of these skills.^[17] There is also evidence to suggest an inverse relationship; that those with more developed motor skills are more likely to participate in physical activity than those with low motor skills.^[61,62]

Bone Health

Childhood and adolescence are recognised as crucial times in bone development due to the rapid growth, modelling and remodelling of the skeletal system.^[63] The tensile and compressive forces from muscular contractions that occur during physical activity can significantly improve bone health.^[64] Numerous cross-sectional studies, randomised controlled trials and longitudinal studies demonstrate that physical activity, particularly involving weight-bearing or bone-loading movement, can increase bone mineral content and bone density in children.^[4,64-66] Achieving optimal levels of bone density and bone mineral content is essential for reaching peak bone mass by early adulthood, thus offsetting the risk of osteoporosis.^[67] A recent review suggested that as little as 10 minutes of moderate-to-vigorous physical activity on 2-3 days of the week could

stimulate such effects on bone mineral density.^[4] Children who are less active may miss the “window of opportunity” to achieve peak bone mass and consequently be at greater risk of osteoporosis later in life.

Psycho-Social Benefits

Children build up self-confidence and self-esteem from successful experiences. Physical activity can provide such opportunities and it is suggested that certain tasks, like shooting a basketball, can create a goal which children can work towards. Regular physical activity has also been noted to improve cognitive function,^[68,69] reduce anxiety and depressive symptoms^[70] and develop positive moral behaviour.^[71,72] In addition, physical activity can provide important opportunities for social interaction which can enable the development of friendships, teach team work and create feelings of self-worth that stem from a sense of belonging.^[73]

Obesity

The prevalence of childhood obesity has reached a global epidemic. Current global evidence indicates that from 1980-2013 rates of overweight and obese children increased by 47.1% ^[74]. While the rate of increase appears to be slowing down,^[74,75] current levels of overweight and obese children worldwide remain dangerously high. An estimated 170 million children (aged less than 18 years) worldwide are now estimated to be overweight.^[50] New Zealand is no exception; presently, 35% of New Zealand children are either overweight (22.5%) or obese (13.0%),^[57] which is an increase from 20.9% and 8.3%, respectively, from the last national survey in 2006/2007.^[76]

Childhood obesity has been associated with a number of immediate psychological effects including depression, low self-esteem and bullying.^[77,78] Overweight children have been ranked as the least desirable friends and, from children's perspectives, associated with laziness and sloppiness.^[79] In relation to risk of chronic illness, evident in obese children are cardiovascular disease biomarkers, including hypertension,^[80-83] glucose intolerance^[80], and hyperlipidaemia^[79], which portrays a worrying picture for chronic disease in adulthood. Furthermore, it has been identified that the most detrimental impact of childhood obesity is the very high likelihood that it persists into adulthood.^[84]

Childhood Obesity and Physical Activity

Ultimately, overweight and obesity physiologically result from a sustained positive energy balance.^[85-87] As a major modifiable component of the energy balance equation, physical activity plays a crucial role in maintaining a healthy weight.^[50,88] The relationship between children's physical activity and obesity has been widely investigated and there are numerous studies showing a positive association between physical activity and healthy body composition in youth.^[89-95] However, current evidence is inconsistent with some studies reporting an absence of significant associations between physical activity and weight status.^[77,96-99] Potentially understanding of how certain active behaviours can influence weight status could advance knowledge of the relationship between physical activity and obesity in children. In addition, although this area has been extensively studied, it is only recently that physical activity has been measured objectively, with many earlier studies investigating the relationship between children's physical activity and obesity using self-reported activity data.^[4] Evidence with valid measures is essential for capturing accurate data on how physical activity can influence childhood obesity and this is an important consideration for future investigations.

Causation of Childhood Obesity

While physical activity heavily influences energy expenditure, the specific causes of obesity are varied and complex.^[77] Numerous genetic, behavioural and environmental factors interact to create an environment in which childhood obesity thrives.^[100] For example, clear associations have also been found between maternal weight,^[101-103] rates of breastfeeding,^[104,105] sleep,^[106,107] dietary intake,^[50,108] parenting styles,^[109,110] socio-economic status^[111] and ethnicity^[57] with excessive body weight in children. Understanding the complex interaction between the numerous mediating factors remains an ongoing challenge for health researchers. Moreover, cross sectional research does not imply causation and emerging research has indicated that there is possibly a bi-directional relationship between obesity and decreased energy expenditure in children.^[112-115] However, further investigations are required to understand this potential bi-directional relationship.

Metabolic Syndrome

A universal definition of metabolic syndrome (MetS) in youth is yet to be achieved. It commonly consists of the clustering of any two or more cardio-metabolic disease risk factors which predict the development of several chronic diseases in adults, including cardiovascular disease (CVD), and type 2 diabetes. These risk factors include central obesity, hypertension, raised triglyceride levels, reduced high density lipoprotein (HDL) cholesterol levels, elevated fasting plasma glucose and insulin resistance.^[54,116,117] The clustering of metabolic risk factors has previously been seen only in adults; however, the presence of one or more risk factors for MetS has now been observed in children and adolescents.^[53,54,116] This is especially prevalent in overweight or obese youth,^[117,118] and the prevalence is reported to intensify with worsening obesity.^[119] It has been suggested that evidence for the relationship between MetS and obesity in youth is of a strength that, regardless of how the metabolic syndrome is defined, its epidemiological presence and relation to obesity in youth are inextricably linked.^[54]

The presence of MetS in children presents a major public health concern, specifically in relation to the development of type 2 diabetes.^[50] Presently, type 2 diabetes is one of four major non-communicable diseases and estimated to be responsible for 4% of all non-communicable disease-related deaths in 2012.^[5] A recent review indicated physical inactivity is a serious risk factor for the development of MetS in youth.^[119] Some studies,^[80,120-123] including a recent review,^[124] have reported positive associations between physical activity and improved metabolic profiles in children. However, there has not been a universal definition of metabolic syndrome,^[124,125] and only a few studies have examined the association using objective measures of physical activity.^[120,121,123] The minimal and optimal amount of physical activity required to prevent the clustering of metabolic risk in children also remains unknown. Overall, the academic consensus is that physical activity of any intensity will benefit the prevention and management of MetS in children.^[54]

Hypertension

Hypertension, a risk factor included in adult metabolic syndrome, has received growing attention in paediatric research.^[126] A widely accepted precursor for CVD, evidence of elevated blood pressure is now being seen in children as young as seven years old.^[51,52,127] CVD is responsible for more deaths per year than any other cause worldwide. This epidemic is not restricted to

developed countries; the African region has the highest mortality from this non-communicable disease.^[5] In New Zealand, CVD is responsible for 30% of all deaths per annum and it is reported that there is a related death every 90 minutes.^[128]

Childhood obesity is a significant risk factor for the development of hypertension. A recent meta analysis reported higher systolic blood pressure (by 4.54mm Hg) in overweight children and 7.49 mm Hg in obese children.^[129] Physical inactivity is also considered a primary lifestyle factor contributing to high blood pressure.^[130] Investigation into the relationship between physical activity, sedentary behaviour and hypertension in children is still in its infancy. Some studies have shown a weak to moderate correlation between physical activity and blood pressure in youth^[82,83,131-133] and this relationship strengthens when focusing on those already with hypertension.^[134] While symptoms for high blood pressure often go without detection, and the earliest age at which those at risk can be identified remains unknown,^[135] early intervention targeting physical inactivity could significantly help to reduce risk factors for high blood pressure and improve life expectancy worldwide.

Summary

Physical activity in children is paramount for their immediate health and there is substantial evidence to support the benefits of children being active each day. Although it is widely accepted that physical inactivity is a risk factor for numerous chronic diseases,^[3] there is some inconclusive knowledge around the impact physical activity can have on childhood obesity, hypertension and risk for type 2 diabetes. However, given the pivotal role physical activity has on energy expenditure and maintaining optimal wellbeing, little doubt remains of the importance of children being physically active.

Physical Activity Compliance

In recognition of the extensive benefits of children being physically active, global guidelines have been developed by the World Health Organisation. These recommendations are based on the minimal amount of physical activity needed to maintain health and offset the risk of chronic disease. The World Health Organisation recommends children accumulate at least 60 minutes of moderate-to-vigorous intensity physical activity (MVPA) daily, and activities which specifically strengthen muscle and bone should be included at least three times a week.^[3] Many countries

have adopted these recommendations as national guidelines, including the United Kingdom,^[136] United States,^[137] Canada,^[138] Australia^[139] and New Zealand.^[59]

It is clear from global evidence that activity levels in youth are low in comparison to the established guidelines in many developed and developing countries.^[3] Outcomes from a recent Global Summit indicated that from 39 countries, only 23% of 11-year-olds achieved 60 minutes of moderate-to-vigorous activity a day.^[6] Out of the countries included in the summit, New Zealand ranked as one of the two with the highest youth activity levels; self-reported data demonstrated that over 60% of New Zealand children meet world activity guidelines (62% female and 72% male).^[6] This was similar to findings from the most recent New Zealand National Healthy Survey (2008/2009), which demonstrated 67.1% of children complied with current physical activity guidelines.^[57]

While self-reported physical activity is a cost effective measurement method, particularly for population based research, there are significant limitations using this method. Only low to moderate correlations have been reported between direct and indirect measures of physical activity.^[140] Recalling physical activity can be a complex task that children and older adults may find challenging to complete accurately.^[141] It is also recognised that social desirability bias can lead to over-reporting of activity.^[142] It is likely that the rates of physical activity for New Zealand children are substantially lower than what has been currently self-reported. Outcomes for other New Zealand studies that have used objective physical activity measures would support this prediction. Investigations using pedometers^[143] and accelerometers^[144] found much lower compliance rates to physical activity guidelines. Of particular concern was the recent finding from a cross-sectional study that no child (mean age, 8 years old) met 60mins of MVPA, and that all children spent 91-96% of their time in light or sedentary activities.^[144] Both pedometers^[145] and accelerometers^[11] are now widely acknowledged for providing a practical, reliable and valid means of quantifying the amount and intensity of physical activity and sedentary behaviour in children. The current inconsistencies highlight a need for further research measuring New Zealand children's physical activity with objective measures to fully ascertain the current prevalence of the children's physical activity.

Irrespective of the measurement techniques employed, there are some clear epidemiological trends in children's physical activity. Consistently more boys than girls meet daily activity

guidelines, which has been reported in numerous large-scale reviews^[58,63,146,147] and population-based research.^[57,139] This is an important consideration in the development of effective and targeted interventions. It is also recognised that children from ethnic minorities frequently achieve less physical activity.^[148-151] This is generally perceived to be due to the higher prevalence of ethnic minorities living in lower socio-economic areas, where poorer infrastructure (parks, playgrounds) and higher crime rates present barriers to physical activity. Moreover, it has been found that those living in the inner city have lower physical activity levels than those in suburban areas.^[152,153] Significant differences in children's objectively measured physical activity in those living in rural areas compared to more developed urban areas have been found in Australia^[152], America^[154], Kenya^[155] and Beijing.^[156] Changes in the built environment of inner cities which are less supportive of physical activity are understood to contribute to this trend.^[27] However, currently research is only starting to emerge on how features of the built environment impact children's physical activity, especially in New Zealand.^[157]

The time periods after school and the weekend present an important opportunity for children to accumulate activity. However, emerging research has indicated that children with low overall physical activity levels are the least active during these time points.^[136,158-160] The European Heart Study involving 1800 9-15-year-olds indicated that during the weekend participants engaged in significantly less objectively measured physical activity.^[159] Similarly, an English study of 175 children 10-11 years old indicated that significantly less total counts of MVPA were conducted for both girls and boys.^[160] Recent New Zealand studies also align with these findings.^[57,144,161,162] These time periods are potentially important to target for physical activity interventions, as this time represents an opportunity for children to partake in activities which are less structured and away from the school environment.

A further concerning trend is that it appears physical activity, particularly MVPA, declines from childhood to adolescence. This pattern has been observed globally and is especially prevalent in girls.^[58,163,164] Data from the most recent New Zealand National survey also supports this trending decline; only 15% of young people aged 20-24 years met recommended physical activity guidelines (30 minutes of MVPA/day), compared with 67.1% of children (60 minutes of MVPA/day).^[57] Longitudinal evidence suggests that patterns of activity established in childhood are likely to track through adolescence and into adulthood.^[8,9,11,165] Childhood therefore

represents a crucial time for the establishment of strong physical activity habits in order to offset the potential decline in activity across the lifespan.

Sedentary Behaviour

A separate classification from physical activity, sedentary behaviour is characterised by any action resulting in minimal or no energy expenditure (less than 1.5 METS) and a sitting or reclining posture.^[56,166] Emerging epidemiological evidence suggests that sedentary behaviour has a number of detrimental health implications which are independent of the amount of daily physical activity engaged in. There have been distinct physiological responses observed with prolonged sitting time, termed inactive physiology.^[167-169] The loss of isometric contractions from skeletal muscles while sitting suppresses lipoprotein lipase activity (thus preventing the uptake of triglycerides and high density lipoprotein production) and reduces blood glucose uptake.^[167] The impact of this process for those with high sedentary behaviour has been seen in increased metabolic syndrome and glucose intolerance in adults, which has been observed even in those deemed to meet physical activity guidelines.^[167]

Technological advances to increase work productivity and minimise physical labour have resulted in the subsequent surge in sedentary activities. Time spent watching television, using the computer or a laptop, playing electronic games, reading, travelling by car, talking on the telephone and using cell phones, iPads™ and iPods™ all contribute to sedentary time.^[170] There has been an explosion of electronic media consumption in the last decade, especially in youth.^[42,170] Children and pre-adolescents are said to spend more time using electronic media daily than any other activity. It was recently reported that 8-18-year-olds spend 7.8 hours a day, seven days a week engaged in electronic media devices which added up to 10 hours and 45 minutes when taking into account “media multi-tasking” (concurrently spending time using more than one medium).^[42]

Currently, reducing sedentary behaviour is a global health strategy and one of nine voluntary global targets.^[130] Many countries are moving to implement suggested guidelines around sedentary behaviour for youth. Some countries, for example England, are recommending reducing the amount of time spent sedentary (without a time limit)^[136]. Other countries, including New Zealand^[57] and Canada,^[138] are suggesting that children and young people spend no more

than two hours in total screen time per day (television, computer, electronic gaming) outside of school time. Recently, the importance of breaking up sedentary time with bursts of physical movement as a public health initiative has also been highlighted.^[167,171]

Prevalence of Sedentary Behaviour

High rates of sedentary behaviour in children are observed worldwide. A large global study of children's lifestyle and obesity rates, The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE), was recently conducted.^[7] Objective sedentary behaviour and self-reported screen time activity were measured in children aged 9-11 years old from a large number of developed and developing countries. Children averaged 8.6 hours of sedentary behaviour a day and 54.2% of children failed to meet screen time guidelines of less than two hours.^[7] In regard to sedentary behaviours of New Zealand children, the latest findings parallel global trends. The most recent national health survey showed that 39.6% of children had two hours or less screen time per day. Given the likelihood of such behaviours tracking into adolescence and adulthood, this recent data depicts a worrying picture. Moreover, sedentary behaviour in children has been associated with a number of negative health consequences. These include sleep disturbances,^[172] an increased consumption of more energy-dense foods,^[173,174] hypertension,^[175] and risk of metabolic syndrome.^[176] A large body of research has focused on the relationship between sedentary behaviour and childhood obesity, indicating a negative relationship.^[7,95,177-179]

The relationship between sedentary behaviour and physical activity in children is less conclusive. Some studies have indicated that low levels of physical activity have been negatively associated with children's sedentary behaviour.^[68,87,177,178,180,181] Other studies, including longitudinal studies, have reported that sedentary behaviour is largely unrelated to time spent in physical activity,^[176,182-185] or obesity.^[186-190] As research into patterns of sedentary behaviour in children is relatively immature, there are a number of methodological issues which may be underlying current inconsistency.

Currently, the degree to which sedentary behaviour prohibits time spent being active remains unknown. The displacement theory suggests that time spent watching television and playing electronic games reduces the time allocated to physical activity.^[95,191] Television watching is most likely to be prohibitive of physical activity, at that specific point in time. However, it cannot be just

presumed that there is a correlation between television viewing and total daily physical activity.^[184] The phenomena of the “active couch potato” is possible, whereby children with high levels of physical activity simultaneously have high levels of sedentary behaviour.^[168]

Television remains the most commonly researched sedentary behaviour.^[68,172,176,179,192-194] It is generally perceived that television watching is a universal activity, thus effective and easy to measure. However, a continued focus on this behaviour is likely to under-report sedentary behaviour as children engage in numerous other sedentary activities such as reading books, learning at school and other forms of electronic media.^[42] In addition, sedentary behaviour has consistently been assessed through self and proxy report.^[183,192-194] Potentially, this has led to under-reporting (parents) or over-reporting (children) of sedentary time from social-desirability bias.^[7] Accurate, reliable measures of sedentary behaviour will be necessary for future investigations to ascertain the degree to which children spend their time inactive.

Emerging Behaviours in Physical Activity

Low levels of physical activity and increasing time spent in sedentary behaviours in children worldwide leaves little doubt as to the urgent attention required. Recent investigations into particular activity behaviours in children have emerged to enable a greater understanding of potential barriers and enablers to meeting recommended physical activity guidelines. This knowledge is crucial for informing effective targeted interventions and for developing supportive environments to initiate necessary behaviour change.

Children’s Independent Mobility

The ability to play, roam and move unsupervised (independent mobility) is a fundamental active behaviour, crucial to children’s physical and psycho-social development. Autonomous free exploration of the neighbourhood provides opportunities for children to make decisions, test their capabilities and develop emotional resilience.^[55,195,196] Independent “free-range” play with peers promotes the formation of social bonds^[18,20] and encourages the practice of group skills including sharing, conflict resolution and leadership.^[12,18,197] Of crucial point, independent mobility (IM) has the potential to substantially impact children’s ability to achieve daily physical activity recommendations.

Unsupervised exploration could be unsafe for young children. However, it is highly conceivable that from the age of seven or eight children can safely negotiate their neighbourhood on their own. Research indicates that from this age, children have the inhibitory control to navigate potential dangers, especially those presented by roads and vehicles.^[198,199] Areas that have been recognised for children to be independent in their neighbourhood include local streets, school, parks, playgrounds, friends' houses and sports facilities.^[33,48,200] O'Brien et al., (2000) categorised these places into either formal (such as school and sports facilities) or informal (such as streets or bush areas).^[48]

Influences on Children's Independent Mobility

Literature has strived to understand the complex environmental and psycho-social influences on children's IM. Socio-ecological models are integral to health promotion as they provide a framework for interventions with multiple levels of influence.^[38] This is underpinned by principles of the Ottawa Charter to integrate environmental, community and personal actions.^[201] There has been a substantial discourse on the interactions between the influencing factors on children's IM, which are very much interdependent.^[13,202,203]

Demographic Influences

Sex

Previous research has consistently shown that boys are repeatedly granted more freedom to play and roam independently than females.^[23,30,48,204,205] The reasoning behind this is manifold: parents are more concerned with their daughters' safety, deeming boys more capable of navigating potential dangers in the street, and girls are urged to contribute more to the running of the household than boys.^[37] There is also the social expectation that girls "prefer" more indoor-based activities rather than the rough and tumble play of boys.^[22] However, recent research indicates the sex divide in children's IM is decreasing,^[49] potentially due to the changes in children's autonomous play.^[202]

Age and Birth Position

Several studies indicate that as children mature their spatial mobility also increases.^[23,35,37,206,207] It is understood that parental judgments of their child's ability to navigate the territory outside the

safety of their own home determines the age at which certain levels of IM are granted.^[208,209] In addition, there is evidence that children's birth place can also influence the freedom to play and roam unsupervised. Children who are not first-borns, or are not only-children, have been reported to gain autonomous freedoms earlier than their first-born counterparts; a benefit of having relative supervision by their older siblings.^[29,210] Potentially, changes to the modern family which have recently been observed, including a decrease in the mean number of children per couple,^[211,212] may consequently influence the IM granted to children today.

Women in Employment

Dual working families are increasingly becoming a new social-norm. In New Zealand, 70% of mothers have returned to the workforce before their child starts primary school.^[213] For many families, having two working parents creates a complex schedule of work, school, home and activities, and children's IM can be affected by this.^[34] In an attempt to save time, children are transported through a "trip-chain" of activities. This is where children are chauffeured taxi-style via a multi-trip series of activities.^[34,214,215] Many children are required to leave for school at the same time as their parents and are taken by car on their parents' route to work.^[34,35,216] Similarly, more children are in daycare and being driven around from a young age^[217]. In New Zealand, pre-schoolers spend four and a half hours in a car per week.^[218] While many of these patterns have evolved from convenience and a need to save time, children are increasingly likely to be highly car dependent from a very young age; they are the "backseat" generation.^[26]

Psycho-Social Influences

Parental Perceptions

Parental perceptions consistently appear to have one of the most significant influences on children's IM. Several papers have postulated parents as gatekeepers to children's unsupervised play.^[13] Parental concern for their child's safety has been highlighted as the main reason why they restrict their child's IM. In particular, fear of traffic-related injuries and stranger danger are factors frequently reported.^[29,30,33,48,219,220] In New Zealand, children (aged 10-14 years) have the highest rate of pedestrian accidents of any age group. The time period after school (3.00-5.00pm) is where the highest number of pedestrian accidents occur.^[221] These statistics are concerning as they highlight the persistent risks of traffic-related accidents children face when coming home

from school.^[222] It has been suggested that parents contribute to the high number of vehicles around schools through a “social-trap”.^[223] This is where parents concerned about the traffic drive their children to and from school, leading to more vehicles being around the school zones. Consequently, there are fewer children on the streets which further reinforces this behaviour.^[216]

Providing the Best

Mention has been made in a number of studies about the social pressure parents feel to “provide their best” for their children.^[224,225] The increased social focus on academic and sporting success^[214] has potentially encouraged a rise in the number of organised after school activities that children partake in.^[35,226] A previous New Zealand study investigating the spatial mobility of children aged 9-11 years old found that a significant number of children were enrolled in a number of activities. In addition, it was noted that some of these activities were a considerable distance away (i.e., the other side of the city). It is plausible that in aiming to provide the best activities, parents chauffeur their children via car to and from these activities. In turn it is likely that opportunities for free play at this time are likely to be decreased.^[34,227]

In addition, parents are faced with more choices for where their child goes to school. Rather than sending their child to the local school, normally within walking distance, parents are influenced by where they would like to send their children.^[214,228] This means the distance children need to travel to school becomes greater and is often perceived (by parents) as too far for walking or cycling to safely.^[216,228] This pattern of behaviour could lead to more vehicles on the road and subsequently fewer children on the street, potentially contributing to the aforementioned social trap.

Neighbourhood Sociability

There is now the increased perception that neighbourhoods are not as safe as they used to be.^[26] This in part will have driven parental fear of strangers,^[29,32,33] which is frequently reported to influence children’s IM. Children going to schools further away from their home residence has also been postulated to reduce the sociability of the neighbourhood space. The decreased presence of local children in the area reduces the opportunities for friendships to develop among neighbourhood children. For children who are granted very little IM this effect is exacerbated.^[34] Social friendships have been identified as important correlates for children’s outdoor play^[33,229]

and the length of time children spend walking.^[36,230] Moreover, the perception of fewer children on the street potentially makes the area appear undesirable, increasing the perceived dangers for others.^[23,30,231]

Children's Perspectives and Public Policy

The social construct of children as dependent, vulnerable and in need of constant guidance has been well noted in the literature.^[36,37,232] There appears to be an increasing separation of children from the adult world and children are no longer viewed as their own agents.^[26] Urban design and policy decisions are adult driven, supporting the cultural ideology that children are unable to navigate public spaces.^[233] There is the potential that as children become segregated and restricted from their local sphere, their sense of responsibility for their environment also diminishes.

To date there has been limited research into children's perspectives on IM and their ability to negotiate the neighbourhood safely. Of the small number of studies that have investigated this area, it appears that children's and parents' views differ significantly. An Australian study of children aged 12-13 demonstrated that the majority of boys (93%) and girls (85%) felt safe walking or cycling in their neighbourhood; conversely, fewer than half of their parents agreed (37.4% parents of boys and 27.3% parents of girls, respectively).^[220] Similar results were demonstrated in a more recent New Zealand study of children aged 10-11 years old.^[36] The findings from this study indicated that over half of the children did not like the way they travelled to school and desired to travel more independently. It was apparent from case study interviews that children were very aware of how their parents felt about them using the neighbourhood and knew of their fears related to traffic and strangers; however, the children felt these fears were unjust, and that they could "look after themselves".^[36] Parents attempting to protect their children from possible dangers could be inadvertently preventing a natural learning process in children.^[232] An increased understanding of children's perceptions of their local area and the disparities between their parents' views could help the development of effective multilevel interventions to support their IM.

Environmental Influences

Vehicle Ownership and Active Transport

There has been a drastic increase in global rates of car ownership, and subsequently heavy traffic volumes dominate local streets. Global rates have risen from approximately 500 million in 1986 to 1.015 billion motor vehicles in use in 2010, and predicted to reach two billion worldwide by 2030.^[28] New Zealand now ranks as the eighth highest in the world for car ownership.^[218] The significant increase in car ownership and use has seen an almost parallel decrease in the use of walking and cycling as transport. In children, this has been most apparent in the decreased use of active transport (walking and/or cycling) to school. Many countries have reported findings that the majority of youth are driven to school, including Australia,^[234] Canada^[235] and Norway.^[35] New Zealand has mimicked international trends. The most common transport mode for children is to be driven by car (92.0%). The number of car trips rose from 19 million in 1989-1990 to 37 million in 1997-1998. Alongside which, walking and cycling by children aged 5-14 years has decreased from an average of two hours and ten minutes per week in 1989/1990, to just under an hour and ten minutes per week in 2006/2009.^[218] Coincidentally, there is now the social expectation that it is the pedestrian's responsibility for their safety, rather than vehicles.^[36,37,236]

Children's Play Space

It has been inferred that a "dehumanisation" of the built environment has taken place. This is particularly in regard to traffic density, urban sprawl and a reduction in green areas.^[14,29] As a result, cities are increasingly less child friendly with fewer play spaces for them to interact and make connections both with peers and their surrounding local area.^[14] There is emerging evidence to indicate an association between these changes in the built environment and the reduction in children's IM. For example, a recent Australian study investigating associations between access to local destinations and children's IM in 10- to 12-year-olds found a significant decrease in the odds of children being independently mobile if they lived on a busy road or close to large shopping centres. Conversely, the odds of IM increased more than 50% for those that lived in neighbourhoods with well-connected, low-traffic streets and access to local recreational destinations.^[237]

In contrast to the outdoor space, oral history research has indicated that previously the private space inside the home was not one in which children used to play.^[26] It has been mentioned that the home was a place where there were strict rules and little to play with.^[238] Recent studies have reported vastly different home environments. Children will often have their own room and a large amount of technological devices available to them. These include television, electronic games, music devices and mobile phones, many of which are available inside children's private rooms.^[42] It appears that numerous features of the urban space are unfavourable for children's "free-range" mobility, while concurrently children are discouraged to be outside, and are enticed inside, by ongoing developments in electronic play devices.

Defining and Measuring Independent Mobility

It is clear that there are multiple demographic, psycho-social and environmental factors influencing children's autonomous movement around the neighbourhood. Accurate, robust evidence is required to found investigations and inform effective multi-level interventions which consider these influencing factors. However, currently a comprehensive understanding of children's IM is limited by disparities in the way it is defined and measured.

Defining Independent Mobility

Although research into the area of children's IM has emerged over the last 40 years, the term "independent mobility" has not yet achieved a precise definition.^[239] Children's independent mobility has traditionally been recognised as the ability of children to play, roam and move unsupervised (i.e., the absence of adult supervision).^[23,48,239,240]

Hillman and colleagues (1990) were among the first to conceptualise IM with the use of the phrases "on their own" and "licence".^[23] The term *licence* referred to children's freedom to do certain activities without adults. Similar to a drivers licence or coming of age legal to drink alcohol, Hillman and colleagues suggested there are also a range of *parental licences* to be independently mobile at younger ages. The particular age these are given reflects parental judgements about the competence of their children to safely navigate the (perceived) dangers outside of the home.^[23]

The term *independent mobility* became more frequently cited following Hillman's landmark study. There was an influx in research in developed countries including Sweden^[241], Denmark,^[35] Australia,^[242,243] New Zealand,^[30] and in other English regions.^[216] Although the word IM has been widely used, it has been open to various interpretations. Numerous terms have been used interchangeably including "independent spatial mobility",^[37,48,238] "travel freedoms",^[242] "independent access",^[30] and "roaming territory".^[243] While all these terms allude to the same concept, exactly how IM is defined will consequently determine how, and what, it is measuring.

Several papers have proceeded to critically examine the term, and key themes have emerged from these in-depth examinations.^[200,216,239,244] The first theme is that IM is not permanent. It is an evolving process of extending capabilities through a complex interaction of constraint and choice. This process is aided with an adaptive "web" of variables, including technology^[48,244] and social connections.^[239] The second emerging theme is the notion that the term *mobility* encompasses a wide range of delineations, which relate to the variety of movement that children engage in during their daily activities.^[200] Mobility can range from regular, everyday movements around the home (including regular school trips and visits to friends and relatives) to long-distance migration and trips sometimes only taken once or twice a year.^[216] It has been identified that some mobility may involve planned, structured routes and other mobility may involve meandering explorative play.^[245] A further important consideration is that mobility can also include both active modes of mobility (walking, cycling, scooter) as well as independent journeys on public transport.^[216]

The traditional definition of IM has portrayed *independence* as being without the presence of adults. However, it has been suggested that children's IM cannot be described solely in terms of the presence or absence of adults.^[239] Several papers have highlighted the importance children's friends and peers can have; being referred to as "contributing actors".^[239] Given the importance of children socialising with their peers,^[246] restricting the definition of IM to either "on their own" or "without an adult" could be limiting. The distinct difference in the supervision of children's IM is becoming more apparent with recent articles emphasising this in their definition. Emerging research is also beginning to allude to the changes technology will bring to this field; for example, children carrying mobile phones or "travel technologies".^[244] Children's IM is in part a social construct and consequently there is also the need for the definition of IM to reflect ongoing societal changes.

Summary

The term independent mobility has been widely used and open to various interpretations. Precise determinants of the term can differ between epidemiological studies according to how this behaviour is measured; specifically the distinction between mobility licences or actual mobility. For the purpose of this thesis, the overarching conceptualisation of the term independent mobility was defined as:

Children's ability to play and travel independently in their neighbourhood either alone or accompanied by peers (without the presence of an adult).

Measuring Independent Mobility

Various methodologies have been employed in previous investigations exploring children's IM however, there remains an absence of a standardised measurement.^[39] This following review critiques current IM measurement techniques and explores the possibilities available for a standardised measurement tool.

Parental Licences

Parental IM licences have become a popular method to measure children's IM following Hillman and colleagues' initial investigation.^[30,43,49,202,222,243,247] Typically asked through a self- or proxy-reported questionnaire, IM licences provide a cost effective methodology for studies involving large sample sizes. However, different characteristics of IM licences have been investigated, including allowances,^[23,30,49] frequency of licences and destinations visited,^[15,43,202] actualised affordances^[204] and territorial range (local and wider IM).^[43,243] Consequently, comparability between studies using these licences have some limitations. It would be important for future investigations to consider the reliability of these licences and ensure consistency across the key licences employed.

Active Transport

Assessing children's use of active modes of transport to and from school has been increasingly used in IM investigations.^[55,216,222,248,249] The journey to and from school offers a specific mobility measure universal to all children. However, reflecting on the previous discourse regarding the

definition of independence, it could be argued whether movement to and from an adult-controlled environment reflects true independence. Through initiatives to increase children's use of active transport, such as walking school buses, it is also possible that this journey is not taken independent of adult supervision.^[250] It was also noted in a recent review that many studies employing this measure have failed to include reliable and valid outcomes.^[16] Overall, active transport provides a measure for a component of children's physical activity. Understanding of how children's active modes to and from school have changed is valuable; however, care needs to be taken when using this as a measure of children's IM.

Photo-voice Methodology

Photo-voice methodology is a participatory observational method. In its simplest form, the process involves participants taking photographs of their neighbourhood, communities and objects of interest^[251]. This methodology has a number of benefits: it offers a unique opportunity to capture observations directly from the participant's perspective, providing a link between the environment and the individual. Photo-voice methodology can result in a rich data set, which can also be used to stimulate further discussion; i.e., around participants' perspectives. In addition, using photographs as a "visual" communication tool can help to alleviate some of the recall difficulties for children.^[251,252] Despite these benefits, only a few studies have employed photo-voice methodology to measure children's IM.^[36,204,229] Potentially, this is due to the cost and complexity of data analysis.^[251,253] The potential to give children ownership in the research process, as agents of valued interest, is worth considering, especially in relation to capturing evidence for multi-level interventions.

Global Positioning Systems

Global positioning systems (GPS) provide an accurate measure of positional location and have become popular in health research for measuring aspects of human behaviour, including travel patterns^[254] and physical activity.^[255,256] The use of GPS offers an accurate method to monitor individual journeys while removing participant bias. GPS can be combined with self-reported diaries and motion monitors, potentially providing a quantifiable outcome of children's IM.

A small handful of studies have conducted explorations of children's actual mobility (real-time IM) through portable GPS devices.^[55,200,239,257,258] However, these have been hindered by a number of limitations including missing data from lost signal^[256] and the high level of processing and data cleaning required.^[259] The most common method to match travel diaries to GPS data is through manual matching, though this is very time consuming and subject of operator subjectivity and error. More importantly, in relation to children's IM a major limitation is that GPS devices do not provide a method of identifying supervised and non-supervised activities.

At present, the time and cost involved with using these devices at a population level is impractical.^[258] For example, in an ethnographic study of 10-13-year-old Danish children it was acknowledged that while a comprehensive data set was collected through the use of GPS, the high cost of the GPS equipment meant that there was a limited budget and only half (n=32) the participants were able to wear GPS devices. In addition, the data analysis process was complex and no clear quantifiable IM data were reported.^[239] Another recent feasibility study of children aged 9-11 years sought to reduce some of the known limitations with using GPS in IM research; this investigation conducted in New Zealand matched GPS and travel diaries using sequence alignments, which yielded promising results, though research in this area is still in its infancy.

Map Drawing

Map drawing is an alternative technique that has the potential to quantify distances and areas where children roam independently. A number of studies exploring children's IM have utilised geographical map drawing to facilitate the recall of travel licenses,^[260] perceived neighbourhood boundaries,^[261] and roaming distances.^[34,205,262] A significant benefit of employing map drawing methodology is that children's travel patterns can be very clear.^[34] Similar to the photo-voice process, with map drawing there is direct involvement from the children and additional information about their individual neighbourhoods can be gathered.^[260] However, there are some inherent limitations including neighbourhood size being restricted to the size of the map, complex data requiring high-level interpretation, and some children may have difficulty completing questions on their own.^[260]

A recent pilot study investigated the correlation between GPS and self-reported child mapping techniques for 5-12 year olds (n=17), in measuring location and distance travelled from home.^[205]

No significant difference was found between the two methods, but high individual error was noted. The researcher's conclusion was that GPS offers a more valid method in comparison to child mapping. However, the benefits of child-mapping techniques were acknowledged, especially for use in large populations and in eliciting more information on children's perceptions and experiences.

Interactive Mapping

Recent advances in the development of online mapping have allowed a more interactive process that can assist in accurately recalling independent licences and distance travelled, while acquiring further information on perceptions and experiences.^[46,47] This methodology lends itself to a mixed methods approach, which has been recently highlighted for its potential to capture the complex nature of children's IM.^[39] A further benefit of online mapping is that neighbourhood size is not predetermined or restricted, which is a limitation of static maps used previously.^[205,260]

Recently, the use of interactive mapping has started to emerge. An online mapping application, The Visualisation and Evaluation of Route Itineraries, Travel Destinations, and Activity Spaces (VERITAS) has been developed for a longitudinal study investigating cardiovascular risk factors in relation to neighbourhood characteristics in French adults (RECORD study).^[263] This application has the potential to provide comprehensive geographically defined estimates of IM; however, it has never been used with children. A similar interactive mapping application, softGISchildren, has been specially designed for the use of children and young people. This application has been trialled for use with 9-15-year-old children with promising outcomes in regard to participants being able to locate meaningful places, draw travel routes to and from school and stimulate discussion around participants' perceptions of health and wellbeing.^[47] Although there are a number of benefits in using interactive mapping to assess children's IM, it is still very much in its infancy and there is a paucity of research in this area. Moreover, there remains an absence of a single standard outcome measure of children's IM, which limits emerging research in this field.

Summary

It is clear from the review of prior research that there are a substantial range of methodological approaches which have been used to measure children's IM. There are benefits and limitations to each of these methods and an underlying issue is the absence of academic consensus in how IM is measured. There is the need to understand differences and relationships between different measures of IM and whether these vary from child and parent perspectives. The emergence of a mixed methods approach offers a comprehensive understanding of the complex nature of children's IM. The use of interactive mapping applications may be promising in this regard; however, further investigation is required to understand the feasibility and accuracy of this methodology.

Generational Changes in Independent Mobility

Research from a number of developed countries suggests that children's IM has declined from previous generations. Hillman's landmark study conducted in England, "One False Move", was one of the first lines of inquiry exploring changes in children's IM.^[23] This research compared a range of children's parental licences from 1971 to 1990 in both England and Germany. The licences related firstly to how children get around (on foot) on their own, including licences to cross roads, to come home from school, to go places other than school and to go out after dark. The second set of licences related to the forms of transport available to young children; being able to cycle on public roads and use buses on their own.

The results demonstrated substantial decreases across most licences, particularly in England; most notably, there was a decrease from 86% in 1971 to 54% in 1990 in children aged 7–11 years old going home from school without adult supervision. It was of important note that German children experienced far less restrictions than their English counterparts; 91% of children in Germany were allowed to come home from school. Two subsequent English studies continued this line of inquiry using the same parental licences in 2000^[48] and 2010^[49] and found further decreases; only 25% of English children were allowed to go home from school alone by 2010. Other investigations in developed countries have also observed reductions in children's IM including the Netherlands,^[26] Australia,^[24] Finland^[25] and Norway.^[35]

The majority of previous research has focused on either children's IM licences or their ability to travel to and from school unsupervised. It is unclear how children's geospatial roaming distances and areas have changed generationally. Moreover, none of these investigations provided a direct generational comparison. It is believed that to date there remains a dearth of research exploring change in IM across directly related participants. Exploring intergenerational change in IM is crucial to accurately assess the extent of the decline, particularly given the influence parental perceptions have on children's spatial boundaries.

More recently, investigations exploring children's current IM levels indicate that some children presently experience heavy restrictions on their spatial boundaries. An Australian study of 212 children aged 8-12 years old found 32% of the participants had an IM range less than 100m, and 12% of all children were not allowed to walk or cycle without an adult.^[260] Likewise, in a recent Canadian study of 856 children (10-12 years old), where parents were asked how often their child is allowed out without adult supervision (either on their own or with a friend), nearly 40% of the participants were never allowed out without an adult.^[15] Similar concerning findings have been found in recent New Zealand studies.^[34,205]

It is apparent that the way children explore, interact and move in the public realm has changed substantially over the last four decades. It is possible that children's IM has declined to a point that for some they are no longer allowed to go anywhere with being supervised by an adult. The long term developmental effects of very low levels of IM remain largely unknown. It has been proposed that this reduction in children's IM is a likely contributor to the concerning levels of children's physical inactivity.^[15,17,43,44,247]

Associations between Independent Mobility and Physical Health Indicators

Independent Mobility and Physical Activity

In their earlier work, Hillman et al. (1990) speculated on the impact of children's IM on physical activity and long term health.^[23] Their findings demonstrated that children who were allowed to cross roads on their own were much more likely to travel to school on their own; a journey generally made by walking. Children with this licence were also less likely to be driven to other places, went to more activities on their own in the weekend, and engaged in more weekend activities in total. Modes of active travel (active transport), including walking and cycling, have

been correlated with the attainment of daily physical activity levels in children.^[264,265] In particular, there has been consistent evidence that children using active transport for the school journey are more likely to achieve physical activity levels beneficial for health.^[266,267] Children with restricted IM are also likely to spend less time outdoors, which likewise has been positively associated with physical activity in children.^[268-270] Furthermore, outdoor play offers unique contributions to children's development through unplanned, sporadic play and the opportunity for children to gather a deeper understanding of their environment.^[14]

To date, only a small number of studies have explored the association between children's IM and physical activity (Table 2-1). The majority of these studies have been conducted in developed countries and have used objective measures of physical activity via either accelerometry^[43,45,55,249] or pedometers.^[271] The present evidence clearly demonstrates a positive association; that is, children who experienced greater IM accumulated more daily physical activity levels. Correspondingly, some studies also suggest that children with greater restriction on their autonomous movement did less physical activity than those who had higher IM. Although these associations were strong, there was significant variation in the IM measures used across each study: there were self or proxy reports of unstructured play,^[264,271] ability to go out in the neighbourhood alone,^[15] ability to walk unsupervised in the neighbourhood^[44,271] and parental permission to go to certain destination-based locations.^[43,45,249] Some studies differentiated between IM being without an adult but including friends or siblings,^[15,243] while some did not.^[44,45,55] Furthermore, in some studies there was a significant range in the age of the participants,^[55,243] which has previously been reported to heavily influence the level of IM granted.^[23,29] While there is some clear evidence to support an association between physical activity and children's IM, an absence of academic consensus in measurement techniques limits the reliability of these findings. Further robust evidence is required in order to empirically establish this relationship.

Independent Mobility and Sedentary Behaviour

Sedentary behaviour has been identified as a significant risk factor for numerous chronic diseases; however, it has been generally neglected in IM research. Although some studies have explored activity levels with accelerometers, only a small number have reported estimates of sedentary behaviour and findings are so far inconclusive.^[15,264] It has been found that for girls, lower levels of IM resulted in less time being sedentary;^[15] another study, however, in opposition

it has been observed that IM made no difference to levels of inactivity in girls.^[264] Interestingly, it has been found that boys with high IM also had high sedentary time.^[264] Conversely, no differences between IM and physical inactivity in boys has also been recently noted.^[15] Given the current dearth of knowledge in this area, further investigation is required in order to understand the potential influence IM can have on children's sedentary behaviours.

Table 2-1. Studies examining the associations between independent mobility (IM) and physical activity (PA)

Study	Objective	Sample	PA Outcome Variable	IM Outcome Variable	PA and IM	Assoc.
Mackett et al., 2007 ^[55]	To determine whether children are allowed out walking without an adult.	N= 162 8-11 years	4-Day PA (RT3 Accelerometers)	Walking trips without an adult.	56% children allowed out. Children allowed out went to more places on their own and spent more time outdoors.	Positive
Page et al., 2009 ^[43]	To investigate whether IM was related to objectively measured PA.	N= 1307 10-11 years	7-day PA (accelerometer Actigraph GTIM).	Self-report "How often are you allowed to go to the following places on your own or with friends (without an adult)' (local shops, big shopping centre, park or playground, sports centre, swimming pool, library, school, cinema, friend's house, amusement arcade, bus stop or train station)" Responses: never/sometimes/often/always.	Children who reported being allowed to visit destinations unsupervised locally (Local-IM) and in the wider (Area-IM) neighbourhood had higher levels of weekday PA compared to those who reported lower levels of Local IM and Area-IM.	Positive
Wen et al., 2009 ^[44]	Assessed how much time children spent playing outdoors after school and the relationship with children's IM.	N= 1974 10-12 years	Self-reported time spent outdoors in a 5-day diary	"Are you allowed to walk on your own, near where you live?" Children were given the options of 'mostly', 'sometimes', 'never'.	Children who had 'sometimes' or 'mostly' been allowed to walk near where they lived were significantly more likely to spend more than half an hour a day outdoors after school (compared to those who were not allowed).	Positive
McCormack et al., 2011 ^[271]	To identify correlates of pedometer based cut-points among 10-12 year olds.	N=1480 10-12 years	7-Day pedometers	Parents proxy-reported "if their child was allowed to play in the street, closest park, playground, playing field or walk in neighbourhood without an adult.	Children with low IM (i.e. not allowed) were less likely to achieve pedometer cut points (n.s).	Positive
Stone et al., 2014 ^[15]	To investigate if children's IM is related to objective PA.	N = 469 10-13 years	7- Day PA (ActiGraph GT1M Accelerometry)	Parents proxy- "In general, how often do you allow your child to go out on their own or with friends without an adult?" Responses: never/sometimes/often/always.	Children with higher IM accumulated significantly more weekday PA MVPA in comparison to children who were never allowed out without an adult.	Positive

Veitch et al., 2014 ^[243]	Examined if IM and territorial range were associated with park visitation among youth	N=311 8–16 years	Self-reported their park use and active transport.	Self report “how often do you usually walk to nearby parks: (a) by yourself; (b) with adult accompaniment; and (c) with friends/siblings (no adults). Response options: never/rarely/sometimes/often/very often.	Those who regularly walked alone to parks and regularly walked or cycled with friends to parks, were significantly more likely to visit a park at least once per week, compared to others.	Positive
Marquez et al., 2014 ^[45]	To determine whether IM is associated with level of MVPA.	N=636 Mean age 11.64 years	7 Consecutive Days (Actigraph accelerometers, model GT1M)	Self-report “How often are you allowed to go to the following places on your own or with friends (without an adult)’ (local shops, big shopping centre, park or playground, sports centre, swimming pool, library, school, cinema, friend's house, amusement arcade, bus stop or train station)” Responses: never/sometimes/often/always.	Odds of having a higher level of MVPA when children have higher independent mobility increase through the MVPA quartiles.	Positive
Scoeppe et al., 2014 ^[249]	Investigated associations between children's self-reported IM and objectively measured light, MVPA and total PA	N= 375 8-13 years	4 Day PA (accelerometer counts Actiheart unit).	‘How do you usually travel to: (1) school; (2) local shops; (3) local friend's houses; (4) local parks and playgrounds; and (5) organised activities. Children also selected accompaniment status (alone, with other children, with an adult) for each destination.	Independent travel to school and non-school destinations were not associated with light, MVPA and total PA. Positive association between independent walking/cycling to school and total PA in boys. Frequent independent outdoor play positively associated with light and total PA. No significant associations between independent outdoor play and MVPA.	Positive

Independent Mobility and Obesity

There is currently a global epidemic of overweight and obesity in children. Meeting daily physical activity guidelines is essential to maintain a normal weight, and physical inactivity is widely recognised as a risk factor for childhood obesity.^[3] Declining rates of children's IM appear to contribute to low levels of activity in children, yet little is currently known about the relationship between IM and children's weight status.^[16]

A number of studies have investigated whether children experiencing more time outdoors are more likely to maintain a normal body weight. Findings have so far been inconsistent, with some studies reporting obese children are more likely to spend less time playing outdoors,^[268,272] while some have not.^[12,15] Similar conflicting outcomes were found in the few studies that have explored associations between children's IM and BMI. A weak but positive correlation between weight status and self-reported IM in English children aged 10-12 years old was found;^[43] contrariwise, no difference in body mass index and IM was found in children of the same age in Canada.^[15] Minimal and inconsistent findings exploring associations between children's body weight and their spatial mobility clearly stresses the need for further investigation in this area.

Chapter Conclusion

Independent mobility is crucial to children's physical and psycho-social development. It appears that there is a substantial body of knowledge indicating a drastic reduction in children's IM due to an interaction of numerous societal changes. However, methodological issues limit a comprehensive understanding of the extent of this decline and the potential impact this has on children's physical activity and maintaining a normal weight status. Childhood is an important time to develop healthy habits of physical activity to offset the risk of chronic disease in later life. The following chapters provide a comprehensive foundation of knowledge regarding children's IM to help develop effective multilevel interventions required to improve the concerning levels of inactivity in youth.

Chapter 3. A Pilot Study Exploring the Measurement of Intergenerational Differences in Independent Mobility

Preface

A systematic review of the literature in Chapter 2 indicated an absence of a standardised, reliable measure of children's IM. Outcomes from the review also denoted a paucity of research investigating the generational change in children's IM with directly related participants. There is a clear need to understand the correlations between dissimilar measures of IM and their feasibility for use in different populations. The purpose of this chapter is to explore the relationship between different measures of IM, including an online mapping application, for use across triads of directly related participants. The findings from this study contribute to wider understanding of measurement methodology in children's IM, and informed the subsequent study of a potential measurement tool to investigate further in line with becoming a standardised technique. This chapter has been published by the peer-reviewed journal *Transport and Health*. Refer to Appendix C for the full paper.

Abstract

Background: A fundamental issue limiting the understanding of children's independent mobility (IM) is the absence of a standardised measurement method. This pilot study explored the use of three different measures of IM to assess intergenerational change and investigated social perceptions in children's unsupervised roaming.

Methods: Data were collected for 45 participants from three directly related generations. IM was assessed and analysed in all participants using three measures: IM Licence (permission to travel unsupervised), IM Index (the summed score from multiple items on a questionnaire) and IM Maximum (maximum roaming distance from participants' residential addresses located on Google Maps). Qualitative data were collected from all participants regarding perceptions of IM.

Results: Significant correlations between IM Index and IM Maximum were observed for child participants ($R^2 = 0.334$), but not for parents ($R^2 = 0.024$) or grandparents ($R^2 = 0.284$). IM Licence was not comparable with either IM Index or IM Maximum. Decreases in IM from grandparent to child were observed for all three measures of IM, with some children experiencing extremely low levels of IM.

Conclusion: The results highlight the need for a standard measurement protocol for IM that facilitates comparability among studies. Maximum IM distance estimated via web-based interactive mapping may be a promising choice in this respect.

Introduction

Children with increased freedom to play and travel in their neighbourhood without adult supervision (independent mobility)^[23,49,245,262] may experience numerous social and physical benefits.^[23,49,216,239] Independent mobility (IM) is fundamental to children's psycho-social development through the facilitation of cognitive skills,^[12,273] social prowess,^[18,19] and emotional intelligence.^[21] Children's IM also provides an important opportunity for the daily accumulation of physical activity that benefits children's short^[17,64,274] and long-term^[63,87,275] health. It has been suggested that children with reduced unsupervised exploration are missing out on opportunities to develop resilience and life skills for the adult world^[55,195] and experience lower physical activity levels than those with increased IM.^[15,17,43,44,247]

Despite the potential benefits of IM, investigation of children's IM over the last 40 years indicates a drastic intergenerational decline. Hillman and colleagues' landmark study found substantial decreases in a range of English children's IM licences (permission to roam on their own) from 1971-1990.^[23] These IM licences reflected how children get around (on foot) on their own, including licences to cross roads, to come home from school, to go places other than school and to go out after dark. The IM licences also related to the forms of transport available to young children; being able to cycle on public roads and use buses on their own. Two subsequent English studies conducted in 2000^[48] and 2010^[49] using the same IM licences found further decreases in children's independent roaming. Particularly noteworthy was the decrease in children aged 7-11 years old going home from school without adult supervision, which dropped from 86% in 1971 to 35% in 1990, decreasing further to 25% in 2010^[49]. Similar reductions have been found in other countries, including Germany^[49], the Netherlands^[26], Denmark, Finland, and Norway.^[35] Furthermore, recent studies in Australia^[260] and New Zealand^[34] that have examined IM suggest that children today have very low levels of unsupervised roaming.

A number of pervasive social changes have propelled children's retreat from the streets. Exponential increases in global rates of car ownership have subsequently placed children at a persistent risk of enduring traffic-related accidents.^[222] A social trap has thus been created whereby concerned parents increasingly chauffeur their children by vehicle,^[216] resulting in more traffic on the roads and fewer children on the streets. Additionally, neighbourhoods have experienced a reduction in social connections,^[210] in part due to the increased ability to access

areas further away from the local area; perceptions that neighbourhoods are less friendly have fueled parental fear of strangers.^[32,209] Media coverage of child abductions and crime has potentially amplified these fears, resulting in even fewer children roaming freely around local streets.^[276]

While several studies have investigated temporal changes in children's IM, it is difficult to compare findings due to heterogeneity in the ways IM has been defined and measured. Traditionally, children's IM has been assessed through self- or proxy-report of licences to roam unsupervised.^[15,23,30,43,49,202,204,222,243,247] These licences reflect parental judgement of their child's ability to safely navigate the neighbourhood on their own. A key limitation of this method lies in the variation of how IM licences are conceptually defined. Different aspects of IM licences have been investigated including allowances,^[23,30,49] frequency of licences and destinations visited,^[15,43,202] actualised affordances^[204] and territorial range (local and wider IM).^[43,243] Consequently, comparability between these studies has some limitations. In addition, there have been inconsistencies between studies using IM licences in how the term unsupervised has been defined. In some studies there has been a focus on either a presence or absence of adult supervision^[23,30,49,202,204,247] and some studies have incorporated the accompaniment of either siblings or friends in the definition of independent mobility.^[15,43,222,243]

Assessment of active transport behaviours to and from school has also been used in previous studies as an IM indicator.^[55,245,248,249,265,277] The school journey provides a clearly defined episode of mobility; however, it may not be undertaken independently. The school journey follows a route often predetermined by adults for which even active modes of transport may be supervised, such as through the use of walking school buses.^[250] Other studies have assessed children's real-time spatial movement via portable global positioning system (GPS) receivers.^[200,240,257,278] GPS receivers provide an objective measure of positional location and can accurately monitor individual journeys while removing participant bias.^[254,255] However, a significant drawback of GPS is their inability to differentiate between supervised and non-supervised activity.

Map drawing is an alternative technique that has the potential to assess both children's licences to roam unsupervised in their neighbourhood, the distance they travel independently and to collect more complete data on the level of supervision. A number of studies exploring children's IM have utilised map drawing to facilitate the recall of travel licences,^[237,260] perceived neighbourhood

boundaries,^[261] and roaming distances.^[34,205,262] Recent advances in the development of online mapping have allowed a more interactive process that can assist in accurately recalling independent licences and distance travelled while acquiring further information on perceptions, experiences and environmental knowledge.^[14,34,46,47] Unlike static maps which previous studies have relied on,^[205,237,260] an additional benefit of online mapping is that neighbourhood size is not predetermined or restricted. Although there are a number of benefits for using interactive mapping to assess children's IM, it is still in its infancy and there is currently an absence of a single standard definition of IM using this method.

It is apparent that a significant issue limiting the understanding of children's IM is the variability in the conception definition of IM and the absence of a standardised measurement method. There is the need to understand differences and relationships between different measures of IM and whether these vary from child and parent perspectives. The aims of this pilot study were to (1) explore the use and comparability of three different measurement techniques to assess current and historical changes in children's IM over three directly related generations, and (2) to assess the social perceptions potentially limiting children's IM today.

Methodology

This cross-sectional pilot study was conducted in Auckland, New Zealand in August 2011 using a mixed methods approach. Written, informed consent and assent were required prior to participating in the study. Ethical approval was obtained from the AUT Ethics Committee (Refer to Appendix A).

Participants

A convenience sample of participants was recruited through existing professional and personal contacts. Participants who met the eligibility criteria were invited to participate and provided written informed consent and assent. Children aged 10-12 years old were eligible; inclusion criteria for the parents and grandparent were to be sex matched and directly related through the same genetic line as the child participant.

Procedures

Data were collected in each participant's home by a trained researcher; in the first instance with the child and parent, and in the second instance with the grandparent. Each participant took part in a semi-structured interview which included demographic questions, three measures of IM, and questions regarding perceptions of IM. The children's data were collected independently, without the presence of their adult relatives.

Measures

Demographic information was collected during the adult interviews. The number of working vehicles, bicycles and child mobile phone ownership was determined. The researcher made notes in regards to urban design including the type of house, street and if there was a back garden.

For all IM measures the child participants reported their current IM allowances and mobility. The parent and grandparent participants recalled their experiences as a 10-12 year old. To assess IM Licence, each participant was asked if they were allowed to go out on their own in the local neighbourhood. They were given the following options as responses: (1) yes, (2) no – only with other children, (3) no – only with an older sibling and (4) no – only with an adult. If 'yes' was answered, participants were then asked "If yes – is there/was there a time limit you are allowed out for". The children's and adults responses were cross referenced by asking the parent/guardian the same question in context "Was your child allowed to go out on his or her own in the local neighbourhood?".

Participants' degree of independent roaming in their neighbourhood was assessed using a questionnaire previously used in another international study to measure children's IM.^[43] They were asked "how often are you allowed to go to the following places on your own or with friends (without an adult)?" For each location (local shops, big shopping centre, park, sports centre, swimming pool, library, school, cinema, friend's house, other outdoor places [beach, river, bush], bus stop or train station and local streets) participants were given the following scale to choose from: never, sometimes, often, or always. Participants were given an additional option of 'I do not go there' for locations that are not available in the area. Each of the responses was assigned a rank (Never = 0, Sometimes = 1, Often = 2, Always = 3) and then summed to give a total score.

The summed total was divided by the number of places the participant went to (excluding those answered 'I do not go there'), which gave an overall IM Index.

Participants' maximum unsupervised roaming distance (IM Maximum) was assessed through the use of a computer-assisted personal interview (CAPI), which took approximately five minutes. Using a laptop computer running the online application Google Maps, participants were assisted to plot their home and then identify the location which was the greatest distance from their home that they were allowed to roam unsupervised (without adult supervision or accompanied by friends/siblings). Using the mapping functions of the Google Maps software, the distance between this maximum roaming point and the participant's home was measured using the street network and following the most habitual route typically taken for this journey.

Participants' viewpoints and attitudes regarding children's current and historical IM were gathered during the semi-structured interviews. Key interview questions to engage conversation around parents and grandparents perspectives included: "are there (or were there) any reasons why your child is not allowed to go to certain places on their own?" and "do you think there is anything different from when you were 10-12 years old for your children today?" Questions for children included: "is there any reason why you do not like to go to certain places on your own?", "what do you think are your parents' reasons?" and "if you were allowed is there anywhere else you would like to go?"

Data Analysis

Means and standard deviations for all descriptive data were calculated and differences between sexes examined using independent samples t-tests. One-way analysis of variance procedures with post-hoc testing were used to investigate differences in IM Index and IM Maximum among the three generations. Statistical significance was calculated using $p < 0.05$. Pearson correlations and regression analysis was conducted to assess the similarity between IM Index and IM Maximum. All analyses were conducted on IBM SPSS (V. 17). No statistical comparisons were made between IM Licence and IM Index/IM Maximum, due to heavily skewed IM Licence data (see results). Interview questions regarding perceptions were systematically analysed by generation for common themes.

Results

A total of 21 children aged 10-12 years (14 male, 7 female), 17 parents aged 34-51 years (8 male, 9 female), and seven grandparents aged 62-73 years (4 male, 3 female) participated in the study. The majority of children (90%) lived in a single detached dwelling; two child participants lived in a unit. The children's homes were situated either on a residential street (66%) or a cul-de-sac (33%) and most (81%) had a back garden. Each family had an average of two vehicles and 4.6 bikes per household. Over half (62%) of the children owned a cell phone. The average number of children per household was 1.6 and 38% of the children had older siblings.

Independent Mobility

IM Index and IM Maximum

Table 3-1 shows the IM Index and IM Maximum for the study sample. Mean IM Index for children was 1.49 (SD = 0.7), parents 2.28 (SD = 0.44) and grandparents 2.54 (SD = 0.28). Males had a higher IM Index than females across all generations. While the mean IM Index decreased generationally from grandparents to parents to children, the difference was significant between parents and children only ($p < 0.01$). The mean IM Maximum travelled by children was 2673m (SD = 1929) and ranged from 200m-7,000m. The mean IM Maximum travelled by adult participants was 5335 (SD = 4940) and ranged from 1,500m-22,000m. Mean IM Maximum for grandparent participants was 7810 (SD = 7064) and ranged from 270m-17,000m. Males had consistently higher IM Maximum than females across all generations. As with IM Index, generational differences in mean IM Maximum were significant between parents and children only ($p = 0.029$).

Figure 3-1 illustrates the relationship between IM Maximum and IM Index for children, parents, and grandparents. A significant correlation was observed between IM Maximum and IM Index for children ($p = 0.568$, $p = 0.007$) and across the pooled data set ($p = 0.452$, $p = 0.002$), but not for parents ($p = 0.117$, $p = 0.655$) or grandparents ($p = 0.741$, $p = 0.057$). Regression analysis revealed a significant linear trend between IM Maximum and IM Index in the child group (IM Maximum = $1.60 \times \text{IM Index} + 0.289$, $R^2 = 0.334$, $p = 0.006$), but not for the parent (IM Maximum = $1.73 \times \text{IM Index} + 1.38$, $R^2 = 0.024$, $p = 0.550$) or the grandparent group (IM Maximum = $15.9 \times \text{IM Index} - 32.6$, $R^2 = 0.284$, $p = 0.126$). The regression model for the pooled data (displayed in

Figure 3-1) showed a significant linear trend (IM Maximum = 2.92 x IM Index – 1.23, $R^2 = 0.205$, $p = 0.002$).

Table 3-1 IM Index and IM Maximum for all participants and by sex

		N	IM Maximum	IM Index
Child	Male	14	2796 (1281)	1.54 (0.59)
	Female	7	2428 (2957)	1.38 (0.9)
	Total	21	2673(1929)*	1.49 (0.7)*
Parent	Male	8	7025 (6508)	2.4 (0.44)
	Female	9	3833 (2522)	2.1 (0.45)
	Total	17	5335 (4940)**	2.28 (0.44)**
Grandparent	Male	4	12400 (5757)	2.75 (0.10)
	Female	3	1690 (1293)	2.26 (0.15)
	Total	7	7810 (7064)	2.54 (0.28)

*Significantly different from parents and grandparents ($p < 0.05$)

**Significantly different from grandparents ($p < 0.05$)

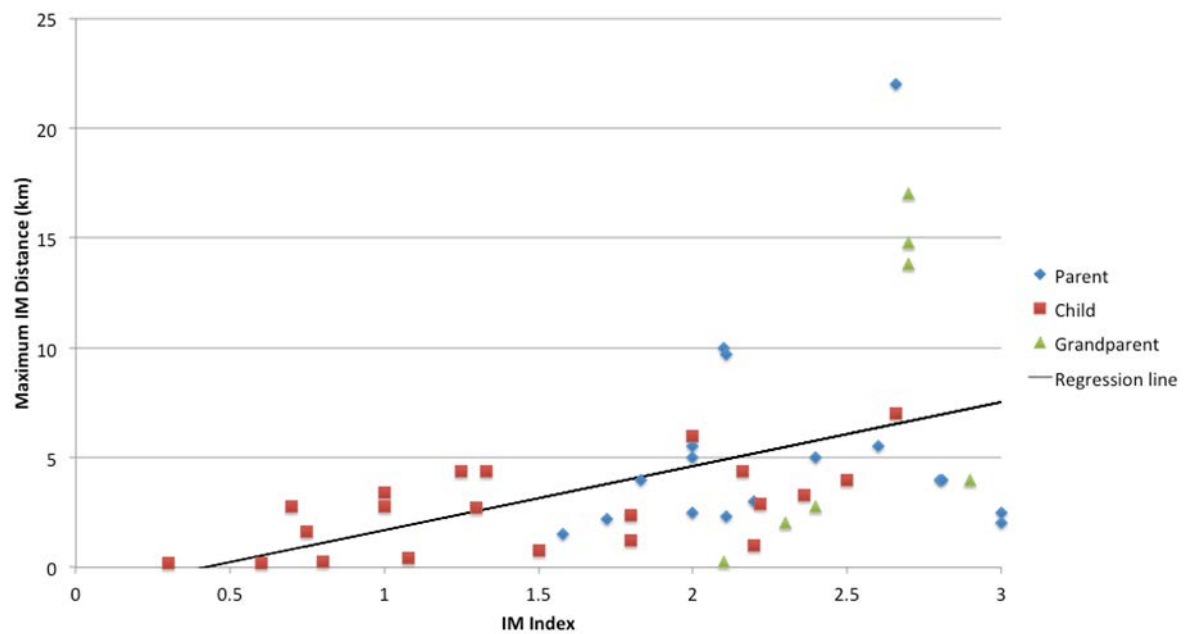


Figure 3-1. Association between IM Maximum and IM Index for children, parents, and grandparent. The linear regression line was fitted to data from all three groups.

IM Licence

Grandparents and adults reported similar IM Licences: all were allowed out in the neighbourhood on their own with minimal restrictions. The time limits put in place were either “to be home for dinner” or “by dark”. Of the child participants, 17 children (12 males and 5 female) were allowed in the neighbourhood on their own but experienced considerable restrictions around where they could or could not play. Six (28%) of the child participants were only allowed out for a set time between 30 minutes and one hour and then were required to be home. Ten of the child participants were allowed out on their own if the location was prearranged and parents knew what time they would be home. Of the children that had access to a cell phone ($n = 8$), they were all required to use these to keep in regular contact with their parents. One male child participant had complete freedom to go anywhere in the neighbourhood on their own and did not have any restrictions in regards to location of play or the amount of time they were out for. Four child participants (2 males and 2 females) were not allowed out on their own at all unless they were accompanied by either a sibling ($n = 1$) or a friend ($n = 3$). In addition, each of these children had to get prior approval from their parents as to the length of time they would be out for, who they were going with and exactly where they were going. Due to the low numbers of participants who were not permitted to travel without adult supervision, meaningful comparisons between IM Licence and IM Index/IM Maximum were not possible.

Qualitative Interviews

There were particular themes that emerged in response to key questions asked in the semi-structured interviews for each generation; relevant quotes have been included to emphasise these themes:

Grandparents

When asked if there were any reasons why they were not allowed to go to certain places either for themselves as 10-12 year olds or for their children (parent participants), none of the grandparent participants recalled any restrictions other than needing to be home by dinner.

“Just needed to be home in time for dinner; we just played in the street with other kids so did not need to travel far.” (Grandparent in response to their own childhood).

All grandparent participants noted drastic changes in the neighbourhood from when they were children to that of their grandchildren today. The significant rise in traffic volume, greater access to drugs, a decrease in neighbourhood sociability, and increased risk of stranger danger were all common changes mentioned. In addition, there was an overall view that children today are very sheltered or (to quote) “mollycoddled”.

“We used to have an open door all the time with people coming in – we never dreamed there would be a day where we would be locking the door with us inside!” (Grandparent participant).

“The biggest difference today is that we do not know our neighbours – it took an earthquake for people to start talking to each other.” (Grandparent participant).

Parents

None of the parent participants could recall any reasons why they were restricted from certain places as a child other than needing to let their parents know generally where they were going and to be home by dark. In regards to perceived changes from when they were 10-12-year-old children, parents’ responses were similar to the grandparents’. The changes most frequently discussed were an increase in traffic volume, speed that vehicles travel, threat of violence and access to drugs. A decrease in neighbourhood sociability, a change in family structure with both parents working, and a rise in organised sport were also commonly mentioned.

In response to the question “are there any reasons why your child is not allowed to go out on their own or to certain places in the local neighbourhood?”, 90% of parents brought up concerns of safety. When analysed for common themes, traffic (62%), stranger danger (47%), darkness (28%), and general safety (28%) were the most common reasons why parents did not allow their children out on their own.

“Yes – (he is allowed out on his own) but everything must be prearranged, the route to school is prearranged and he has his cell phone. If he is not home by 4pm I worry.”
(Parent of an 11-year-old boy).

Children

All child participants were aware of the reasons their parents restricted them from going to certain places (safety, traffic or strangers). However, 71% of the children had no concerns about travelling to certain places on their own. Of those that did have concerns, all responded with a fear of strangers, and two child participants mentioned a fear of traffic-related accidents. The majority of children (76%) could identify places they would like to go to if they were allowed. The places most frequently mentioned were shopping malls, movies and friends' houses. There were no significant sex differences.

"My parents are concerned about my safety but I feel independent enough."

(Male, 11 years old).

"Mum knows I can look after myself but I guess roads are busy."

(Female, 11 years old).

Discussion

Children's IM is a growing research field whereby differences in measurement procedures and definitions of IM currently hinders further understanding. The primary purpose of this pilot study was to explore and compare three measures of children's IM across three generations. Each of the measures implemented (IM Licence, IM Maximum and IM Index) were feasible and acceptable for all participants to use irrespective of age and sex. The self-reported nature of the IM Licence and IM Index means the questions could be used as part of a larger survey or questionnaire, subsequently offering a low cost, quantifiable measure of children's independent mobility applicable for large sample sizes.^[23,43,49]

However, as with previous studies, the complexity in conceptual definition of IM Licences has limited the comparability of IM Licence as a measure. The decision for parents and caregivers to grant IM licences is rarely a 'yes' or 'no' decision. There are contingencies which affect their decision-making in certain circumstances.^[239] This was apparent through the responses to IM Licence questions and the semi-structured interviews, whereby there was variation in the rules around the allowances given for children today, including set time frames, companionship, pre-arranged locations and the use of a cell phone for ongoing parental contact. These data would

support the need for a differentiated measure of children's IM which accounts for the extent in which children's independence can vary.

The IM Maximum utilised map drawing methodology similar to previous studies,^[34,260] yet with a specific quantifiable variable. The mapping methodology provided an interactive experience for participants, and the various functions of Google Maps (including the identification of key landmarks, zooming options and 'street view' perspectives) likely aided participants' recall. In addition, the data were easily interpretable, a limitation previously identified for static mapping techniques.^[205] While the estimates of IM Index and IM Maximum were significantly correlated, the proportion of explained variance (R^2) ranged from 2.4% (n.s.) in parents to 33.4% in children. These findings suggest that to a certain extent these measures are conceptually related; i.e., the maximum roaming distance may directly influence choice of destinations and the frequency visited (or vice versa). However, there is a need for academic consensus on the definition and measurement of IM to facilitate comparability and accurate interpretation of future studies. It is recommended that the use of web-based interactive mapping offers the greatest potential to provide an accurate and in-depth measure of children's current IM distance, including possible inhibitors and enhancers of autonomous movement in the neighbourhood.

The results also indicated substantial generational decreases in all measures of IM (IM Licence, IM Maximum and IM Index). Mean IM Index levels and mean IM Maximum decreased slightly (but non-significantly) between grandparents to parents, with relatively large decreases from parents to children. Only one child from today's generation was permitted the same unrestricted licence to roam and travel freely in the neighbourhood that their parents and grandparents experienced. These findings align with earlier research^[23,35,48,49] that indicates children today experience much less freedom to play and explore their neighbourhood than their parents and grandparents did at the same age.

In regards to IM levels of children today, the findings of this study parallel current research. Children's mean IM Maximum was 2,673m (\pm 1929). Another New Zealand pilot study investigating the measurement of IM in 17 children aged between 5 and 12 found similar maximum roaming distances.^[205] It was also noted that some children had very low levels of IM; three children in this study had a maximum roaming distance of 250m or less. In some instances children experienced severe restrictions on their play: for example, some children were required

to have their outing prearranged at a designated location, or were confined to a 30 minute time limit. Similar results were found in an Australian study of 212 children aged 8-12 years old, with 32% of the participants having an IM range less than 100m, and 12% of all children not being allowed to walk or cycle without an adult.^[260] Likewise, in a recent Canadian study of 856 children (10-12 years old), where parents were asked how often their child is allowed out without adult supervision (either on their own or with a friend), nearly 40% of the participants were never allowed out without an adult.^[15] While the long-term developmental effects of such low levels of IM is uncertain, there is emerging evidence to suggest that low IM may negatively impact children's physical and psycho-social development.^[17,43,279]

Previous research has reported consistent evidence that boys are granted more IM than females.^[23,30,48,204,205] It is understood that the reasoning behind this is twofold: that parents are more concerned with their daughters' safety, and that girls are encouraged to take up household responsibilities to a greater extent than boys.^[37] While sex differences were apparent in parents and grandparents in the present study, there was little variation in the IM levels between sexes in the child participants. It is possible that as children's IM levels drop to a very low level, sex differences experienced previously will no longer be apparent. Indeed, one of the most recent studies in this area was unable to find differences in IM between boys and girls.^[49]

The qualitative findings from this study demonstrate that for previous generations, parents had little or no concerns about their children roaming freely in the neighbourhood. By comparison, parents today expressed a number of concerns for their children's safety, especially in regards to traffic and "stranger danger". These fears have been well noted in previous literature as significant reasons why children's IM is restricted today.^[29,30,32,33,220] It is highly likely that parental concern for their child's safety and the change in neighbourhood sociability have resulted in children's IM licences and independent roaming being more restricted. Conversely, children in this study did not share the same concerns regarding their safety as their parents. They expressed a desire to have more autonomous roaming and frustration at feeling capable to negotiate the neighbourhood safely while being heavily restricted from this. These findings are comparable to those from a study conducted in Australia^[238] and another New Zealand study examining children's perspectives on their IM.^[36]

Given the exploratory nature of this pilot study and the small sample size, caution needs to be taken when making generalisations. In addition, the former home addresses of some of the grandparents had changed from a rural area to an urban area, and in some instances were difficult to locate exactly on Google Maps. It is possible this limited the recall ability of this generation. Finally, it was more difficult to recruit grandparent participants compared to child and parent participants due to unavailability, resulting in a proportionately lower sample size; this could potentially present sampling bias issues in future studies.

Conclusion

In conclusion, all measures of IM utilised in this pilot study were feasible and practical to use across three directly related generations. The suggested correlation between IM Index and IM Maximum is worth exploring further, especially the use of interactive mapping technology given the potential to accurately measure various important facets of children's IM. The findings that children's autonomous movement has declined significantly from earlier generations is concerning and further research is warranted to investigate possible associations with aspects of children's health.

Chapter 4. The Relationship between Interactive Mapping and Traditional Measures of Independent Mobility.

Preface

Review of the literature in Chapter 2 and exploration of measures in Chapter 3 clearly indicate the absence of a standardised measure of children's IM. Our current understanding of this fundamental behaviour is hindered as a result. While parental IM Licences remain a popular measurement technique, there is variation in how these licences are defined. The outcomes from Chapter 3 indicated that interactive mapping has the potential to become a standardised IM measurement technique; however, research using such applications is sparse and it is not known how they compare to more traditional indicators of IM. The purpose of this chapter is to investigate the relationship between measures of children's IM derived through an interactive mapping application with two traditional measures of IM. The outcomes of this study will provide a timely contribution to IM methodology literature and inform the measurement choice for the following chapters. This chapter has been submitted to the peer-reviewed journal, *Journal of Children's Geographies*.

Abstract

Background: There is currently an absence of a standardised definition and measurement protocol for determining children's independent mobility (IM). The adoption of a mixed methods approach may provide a more comprehensive and reliable assessment technique. To this end, the development of an interactive online mapping application offers the potential to capture geographically-defined mobility data. The aim of this study was to compare children's independent roaming areas collected using VERITAS-IM (an online mapping application) with traditional IM measures.

Methods: Independent parental licences (IM Licence) and allowances to go to certain locations in the neighbourhood unsupervised (IM Index) were collected through a questionnaire. Participants then completed a computer-assisted personal interview using the VERITAS-IM online mapping application, where they geolocated places they had been independently mobile (either by themselves or with friends, in the absence of an adult) in the previous six months and last seven days. Geospatial data were imported into ArcGIS; novel measures of independent mobility destination (IMD) and boundary (IMB) defined area and distance were generated and compared to (1) IM Licences (parental permission to travel without adult supervision) and (2) an IM Index (calculated from the summed ranked responses of a location based questionnaire).

Results: Data were collected and analysed for 219 children aged 11-13 years. Significant relationships were found between the VERITAS-IM derived measure IM Boundary Area (IMB Area) and traditional measures of IM (IM Licence and IM Index). A significant difference was found between IMB Area and IMD Area for both 7-days (-1.01 km²) and 6-months (-0.528 km²) as well as between IMB Distance and IMD Distance for 7-days (-0.747 km). No significant difference was found between IMB Distance and IMD Distance for 6-months (-0.194 km).

Conclusion: The data indicate that the perceived degree of independent mobility in children is heavily dependent on the assessment method. The outcomes of this study further highlight the need for a consensus in the definition and measurement of unsupervised mobility in youth. Combining the VERITAS-IM online mapping application with traditional IM indicators in future research could provide complementary information that leads to a richer understanding of how and why children travel independently.

Introduction

Children's independent mobility (IM) is defined as the freedom to play and travel in the neighbourhood without adult supervision, either alone or accompanied by peers.^[13] The benefits of independent, spatial movement for children's health is well recognised. Children's IM has been associated with increased physical activity^[15,45,277] and improved social interactions,^[19] cognitive development,^[12,273] and self-efficacy.^[21] It has been proposed that children who experience restrictions on their ability to roam independently miss opportunities for fundamental physical^[15,17,43,247] and psycho-social development.^[55,195] However, there is compelling evidence that children's IM has declined over the last four decades.^[35,48,49,280] The potential impact of declining IM on children's wellbeing^[17] has resulted in a growing body of literature in this area.^[39]

Investigation into current rates of independent roaming has been conducted in a number of countries. Recent studies have examined children's IM in Canada,^[15] Belgium,^[247,277] Australia,^[243] Portugal^[45] and the United Kingdom.^[43,281] However, comparability between these studies is limited due to disparities in how IM has been defined and measured.^[39,277] Children's IM has previously been determined through self- or proxy-reported parental licences (parental permission for children to go and/or travel to certain places on their own),^[15,23,30,43,49,202,243,247] active transport behaviours to and from school,^[55,248,249] photo-voice methodology,^[36,229] and portable global positioning system (GPS) receivers.^[200,257] There are strengths and limitations to each of these methods^[280] but there is currently no consensus for a standardised measure.^[39] Conceptual differences between where children are allowed to roam and where they actually roam further cloud the issue. Accurate, standardised measurement of IM is crucial for collecting longitudinal data, identifying populations at risk of low mobility and to gain an understanding of the associations that inhibit or promote IM.^[13,258] Accordingly, this information is also vital for the development of social and environmental policies, which can impact important planning decisions, including neighbourhood design.^[13]

It is acknowledged that the determinants of children's IM involve a complex interaction of numerous environmental and psychosocial variables at government, community and individual levels.^[13,202] Moreover, children's natural autonomous roaming in the neighbourhood is often unstructured and includes a range of informal environs not specific to a certain distance or location.^[13] One-dimensional measurement techniques, such as 'binary' parental licences (e.g.,

Do you allow your child to cross main roads by themselves?) or singular maximum distances, do not capture these environs and may not provide the full picture of a child's spatial mobility. Recently, it has been suggested a mixed methods approach to collecting children's IM data is required to provide a multidimensional understanding of how and why children travel independently.^[39]

Online mapping has emerged as a potential technique to accurately recall parental licences and independent distances travelled while acquiring more comprehensive information on perceptions, experiences and spaces.^[34,46,47] Research using soft GIS mapping techniques in children have yielded encouraging results in this regard.^[47] Chapter 3 explored IM in New Zealand children aged 11-13 years by measuring the maximum distance travelled independently (IM Maximum) from the home residence via publicly available online mapping software (Google Maps). A positive correlation was found between IM Maximum and a more traditional measure of IM, an index of perceived allowances ($p = 0.568$, $p = 0.007$).^[280] This finding highlights the potential of online mapping to provide an accurate, quantifiable measure of children's IM. However, functional limitations in the public mapping software precluded the capture of other potentially influencing variables such as travel mode, companionship and journey frequency. These have been identified as factors influencing children's IM and could be collected with a custom-designed interactive mapping programme.^[282]

The Visualisation and Evaluation of Route Itineraries, Travel Destinations, and Activity Spaces (VERITAS) is an advanced online mapping application with the potential to provide comprehensive geographically defined estimates of IM. Through a computer-assisted personal interview (CAPI), VERITAS combines survey questions and electronic maps to help promote recall of allowances and accurately geolocate independent locations, boundaries and mobility spaces.^[46] VERITAS was originally developed for a longitudinal study investigating cardiovascular risk factors in relation to neighbourhood characteristics in France (RECORD study).^[263] A recent study has assessed the feasibility of using VERITAS with an adolescent population (12-18 years old).^[282] Given there is consistent evidence to demonstrate that older children are granted greater independent licences,^[23,35,48,202,207] trialing VERITAS on a pre-adolescent population is warranted. As the use of online mapping to measure IM is still in its infancy, it is also important to understand the relationship between conventional measures of IM and those derived from VERITAS. The aim

of this study was to compare estimates of IM distance and area collected using VERITAS with two traditional IM measures.

Methodology

Participants and Procedures

All children from four intermediate schools (school years 7-8) in the Auckland region were invited to participate in the study. Schools were purposely selected to obtain participants from a range of socio-demographic and ethnic backgrounds. Two schools had the highest socioeconomic decile rating (10), while the third had a decile rating of 6, and the fourth a decile rating of 3. All children were given an information sheet, a questionnaire and consent/assent forms to take home. Only children who gave their written assent and had their parent or guardian provide written consent were selected to participate in the study. At a designated time during school hours (between July-November 2013) the children completed a CAPI under the supervision of a research assistant. The research assistant explained the protocol of the CAPI, which was completed on a laptop computer running an online mapping programme (VERITAS-IM) and took approximately 20 minutes. Ethical approval for the study protocol was obtained from the AUT Ethics Committee (Refer to Appendix B).

Questionnaire

Demographic information including sex, ethnicity, and the number and age of siblings were collected via a questionnaire (See Appendix D for children's questionnaire and Appendix E for parent's questionnaire). Two key measures of children's IM were also collected: IM Licence and IM Index. Parental licence questions (IM Licence) were replicated from those used in earlier studies.^[23,30,49] Participants were asked if they were allowed to do the following either by themselves or with friends (without an adult): travel to and from school, cross main roads, cycle main roads, catch a bus/train, or go out after dark. Participants were given the option to respond with either "yes", "no", or "not sure".

IM Index was derived from a questionnaire used in a previous international study,^[43] and has been previously trialled in a pilot study.^[280] Participants' degree of independent roaming (alone or with friends, without adult supervision) to 12 locations (local shops, big shopping centre, park, sports

centre, swimming pool, library, school, cinema, friend's house, other outdoor places [beach, river, bush], bus stop or train station and local streets) was reported. Frequency of allowance to go to these locations was selected from four options; never, sometimes, often, or always. In the instance certain locations were not available participants could select an option "I do not go there". The responses were assigned a rank (never = 0, sometimes = 1, often = 2 and always = 3), summed to give a total value, which was then divided by the number of locations (excluding those of "I do not go there") to calculate a final IM Index. Neither of the questionnaire-based estimates of IM provides geospatial information.

VERITAS-IM

The original VERITAS application (VERITAS-RECORD)^[46] was translated from French to English and customised specifically to investigate children's IM (VERITAS-IM). A series of eight key questions were populated within the interactive maps, which harnesses embedded Google Maps functionality. Initially, participants located their primary home residence which forms a central location point for the remaining interactive mapping questions (1). Participants were then guided to geolocate places where they had been independently mobile (either by themselves or with friends, in the absence of an adult) in the previous six months (2). For each location, information on transport mode, frequency and companionship was also collected. Participants then identified which locations were visited in the last seven days (3). Data on locations for organised sport (4), locations participants desired to be independently mobile (5), and the transport route to (6) and from school (7) were then collected. The final question asked participants to draw a polygon shape around their maximum perceived IM area; the area around their home where they can be independently mobile (8). All data were saved to a secure server at the completion of the survey.

Creation of VERITAS-IM Measures

VERITAS map and questionnaire data were downloaded from our server and imported into ArcGIS 10.1 (ESRI, Redlands, CA, USA) before being visually inspected for any errors. The VERITAS data were used to create six distinct measures of IM in ArcGIS displayed in Figure 4-1: IM Boundary Defined Area, IM Boundary Defined Distance, IM Destination Defined Area (6-Months and 7-Days) and IM Destination Defined Distance (6-Months and 7-Days). IM Boundary Area (IMB Area) was calculated as the area inside the perceived IM boundary polygon.

IM Boundary Distance (IMB Distance) was calculated as the Euclidean distance (i.e., as the crow flies) from the home residence to the furthest point in the perceived IM boundary polygon. IM Destination Area was calculated using convex hull geometry techniques, whereby all locations identified by participants as being travelled to independently during the last 6-Months (IMD Area 6-Months) and 7-Days (IMD Area 7-Days) were enclosed in the smallest possible convex polygon, respectively. IM Destination Distance was calculated as the Euclidean distance from the home residence to the furthest identified location travelled to independently in the last 6-Months (IMD Distance 6-Months) and 7-Days (IMD Distance 7-Days). If the participant did not travel anywhere, they received a zero (i.e., the boundary of their residence was not included).

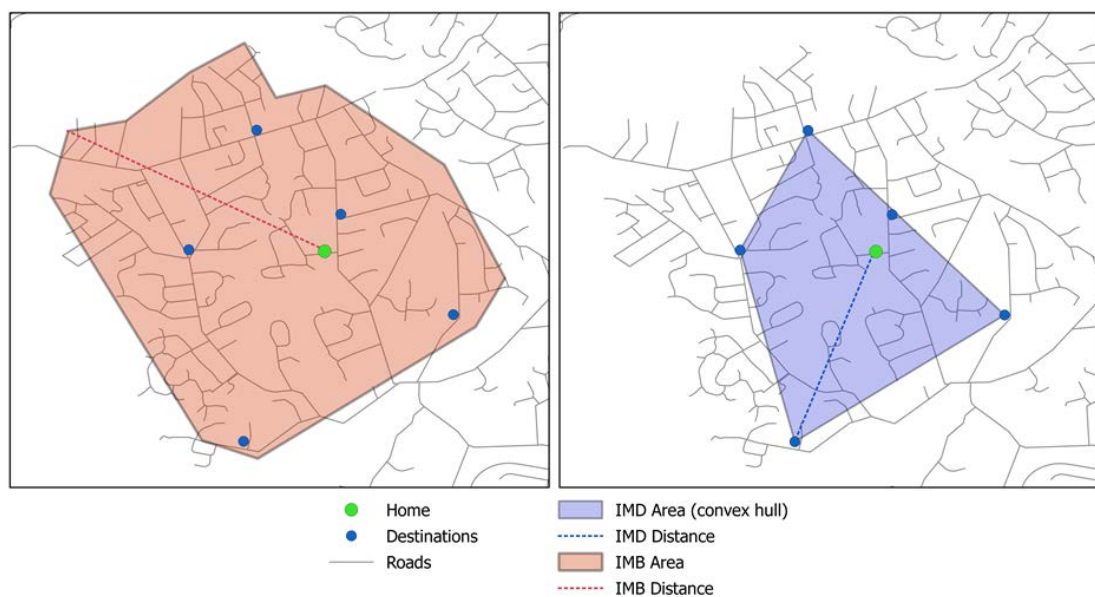


Figure 4-1. VERITAS-derived measures of independent mobility

Data Analysis

Observation of the descriptive statistics revealed that none of the IM variables were normally distributed, and subsequently non-parametric techniques were used throughout the analyses. IM Index was compared with IMB Area and IMB Distance using Spearman's rank order correlation and linear regression. Differences in IMB Area/Distance by IM License were assessed using Mann-Whitney U tests. Differences between IMB Area/Distance and IMD Area/Distance (both 7-days and 6-months) were quantified by calculating the median percent difference and 95% limits of agreement. A negative percent difference indicates IMD underestimation of the IMB median values, while a positive percent difference indicates overestimation. The consistency of percent

difference across the spectrum of Area/Distance estimates was investigated using Spearman's rank order correlation. Statistical significance was set at $p < 0.05$, and all analyses were conducted using IBM SPSS Statistics (V. 20).

Results

A total of 219 children (113 male and 106 female) aged 11-13 (age calculated from year of birth as at December 2013) agreed to participate in this study. The majority of participants were of European descent ($n=161$, 74%), Maori/Pacific Island ($n=21$, 10%), Asian ($n=16$, 7%), and other ($n=7$, 3%); 6% were not specified. Number of siblings ranged from 0-6, mean 1.9 (SD=1.3).

A significant correlation was observed between IM Index and IMB Area ($\rho = 0.462$, $p < 0.001$) and between IM Index and IMB Distance ($\rho = 0.409$, $p < 0.001$). Subsequent regression analysis revealed a significant linear trend between IM Index and IMB Area (IMB Area = $3.95 \times \text{IM Index} - 0.98$, $R^2 = 0.10$, $p < 0.001$) and between IM Index and IMB Distance (IMB Distance = $0.99 \times \text{IM Index} - 0.70$, $R^2 = 0.12$, $p < 0.001$). In other words, the IMB Area increased by nearly 4 km² with every one unit increase in IM Index, whereas IMB Distance increased by 1 km across the same change in IM Index; however, only 10% and 12% of the variance in IMB Area and IMB Distance, respectively, was explained by IM Index. In addition, IMD Area estimates showed that 26.0% of children did not independently travel to any destinations in the 7-day period, with 7.8% not independently travelling in the 6-month period.

Table 4-1 shows the median IMB Area grouped according to the six parental IM Licences. The majority of participants were permitted to travel to and from school, cross main roads, and travel on buses/trains unsupervised (69-88%). Few participants were permitted to cycle main roads or be out after dark unsupervised (17-46%). There was a clear link between all licences and perceived IMB Area (with the exception of the out after dark licence), such that the presence of a parental IM restriction was associated with a significantly smaller IMB Area (difference range: 1.26 to 1.52 km²). The median IMB Area ranged from 1.46 to 2.45 km² in participants who were permitted to travel unsupervised in the six selected contexts, and from 0.12 to 0.43 km² in participants who were not.

Table 4-1. Median IM Boundary Area (IMB Area) grouped by IM Licences.

Licence		IMB Area (km ²)			
		N	Median	IQR	Min, Max
Allowed to travel to school unsupervised	Yes	180	1.46	0.38, 5.04	0, 75.8
	No	32	0.18*	0.02, 1.19	0, 30.8
Allowed to travel from school unsupervised	Yes	187	1.49	0.38, 5.12	0, 75.8
	No	25	0.12*	0.02, 0.80	0, 6.1
Allowed to cross main roads unsupervised	Yes	180	1.48	0.38, 5.16	0, 15.8
	No	28	0.22*	0.06, 2.19	0, 30.9
Allowed to cycle main roads unsupervised	Yes	83	2.45	0.72, 7.65	0, 67.6
	No	96	0.43*	0.10, 2.26	0, 75.8
Allowed to travel on buses/trains unsupervised	Yes	129	1.91	0.48, 7.43	0, 75.8
	No	59	0.39*	0.11, 1.64	0, 7.9
Allowed to be out after dark unsupervised	Yes	31	2.45	0.38, 5.22	0, 59.7
	No	149	0.8	0.20, 3.60	0, 75.8

*Significantly different from: "Yes" ($p < 0.05$).

Table 4-2. Median IM Boundary Distance (IMB Distance) grouped by IM Licences

Licence		IMB Distance (km)			
		N	Median	IQR	Min, Max
Allowed to travel to school unsupervised	Yes	180	1.68	0.86, 2.81	0.01, 16.52
	No	32	0.77*	0.43, 1.77	0.03, 9.81
Allowed to travel from school unsupervised	Yes	187	1.72	0.89, 2.90	0.01, 16.52
	No	25	0.57*	0.27, 1.61	0.03, 3.27
Allowed to cross main roads unsupervised	Yes	180	1.68	0.86, 3.07	0.02, 16.52
	No	28	0.85*	0.47, 1.78	0.03, 10.47
Allowed to cycle main roads unsupervised	Yes	83	2.15	1.12, 3.89	0.02, 16.52
	No	96	0.99*	0.48, 1.92	0.03, 10.83
Allowed to travel on buses/trains unsupervised	Yes	129	2.02	1.07, 3.63	0.02, 16.52
	No	59	0.91*	0.47, 1.78	0.03, 3.89
Allowed to be out after dark unsupervised	Yes	31	1.84	0.89, 2.95	0.02, 16.52
	No	149	1.36	0.64, 2.40	0.03, 11.53

* Significantly different from "Yes" ($p < 0.05$).

Table 4-2 shows the median IMB Distance grouped according to the six parental IM Licences. Excluding the licence to go out after dark, there was a distinct relationship between all licences and IMB Distance. The presence of a parental IM restriction was associated with a significantly smaller IMB Distance (difference range: 0.86 to 1.16 km). The median IMB Distance ranged from 1.68 to 2.15 km² in participants who were permitted to travel unsupervised in the six selected contexts, and from 0.57 to 1.36 km² in participants who were not.

Comparisons between IMB Area, IMD Area 6-Months, and IMD Area 7-Days are presented in Table 4-3. Area values calculated using recalled destinations (IMD) were significantly lower than boundary area estimates (IMB). On average, IMD Area underestimated IMB Area by 100% (7-day method) and 88% (6-month method), with differences in the two methods noticeably greater for males than for females. Furthermore, the degree of underestimation was consistent across the distribution of IMB Area values. Similar results were observed between IMB Distance and IMD Distance when the latter was determined over seven days, with a median underestimation of 67% (Table 4-4). In contrast, the two methods were more equivalent when IMD was determined over six months; in fact, the percent difference was significantly different from zero in males only.

Table 4-3 Comparisons between VERITAS IMB Area and IMD Area (6 Months and 7-Days)

	N	IMB Area (Median, IQR)	IMD Area (Median, IQR)	Difference in area ^A (Median, IQR)	ρ IMB, IMD ^B	Median difference ^C (%)	P ^D	ρ IMB, %diff ^E	95% LOA ^F (%)
7-days									
Male	113	2.08 (0.404, 5.88)	0.002 (0.000, 0.134)	-1.82 (-5.57, -0.359)	0.363*	-99.9	0.000	0.036	-100, 104
Female	106	0.639 (0.180, 2.46)	0.001 (0.000, 0.021)	-0.529 (-2.05, -0.155)	0.437*	-99.9	0.000	0.074	-100, 249
All	219	1.26 (0.304, 4.53)	0.002 (0.000, 0.081)	-1.01 (-4.38, -0.192)	0.414*	-99.9	0.000	0.064	-100, 155
6-months									
Male	113	2.08 (0.404, 5.88)	0.254 (0.003, 2.22)	-1.30 (-3.92, -0.095)	0.546*	-88.9	0.000	0.100	-100, 2740
Female	106	0.639 (0.180, 2.46)	0.121 (0.001, 0.874)	-0.212 (-1.44, -0.003)	0.660*	-86.2	0.000	0.185	-100, 1340
All	219	1.26 (0.304, 4.53)	0.160 (0.002, 1.49)	-0.528 (-2.68, -0.038)	0.595*	-87.9	0.000	0.112	-100, 2370

^A Difference in area = IMD Area - IMB Area^B Spearman's rank correlation coefficient for IMD Area and IMB Area; * $p < 0.05$ ^C Percent difference = (Difference in area / IMB Area) x 100^D Probability that median percent difference = 0 (One-Sample Wilcoxon Signed Rank Test)^E Correlation coefficient between the IMB Area and the percent difference^F 95% limits of agreement = median percent difference +/- 2.5th and 97.5th percentiles

Table 4-4. Comparisons between VERITAS IMB Distance and IMD Distance (6 Months and 7-Days)

	N	IMB Distance (Median, IQR)	IMD Distance (Median, IQR)	Difference in distance ^A (Median, IQR)	ρ IMB, IMD ^B	Median difference ^C (%)	p ^D	ρ IMB, %diff ^E	95% LOA ^F (%)
7-days									
Male	113	1.88 (0.950, 3.24)	0.536 (0.000, 1.49)	-0.959 (-2.14, -0.230)	0.324*	-67.7	0.000	-0.024	-100, 507
Female	106	1.20 (0.606, 2.15)	0.0523 (0.000, 1.34)	-0.488 (-1.34, -0.063)	0.396*	-63.4	0.000	0.084	-100, 868
All	219	1.57 (0.734, 2.72)	0.531 (0.000, 1.41)	-0.747 (-1.77, -0.135)	0.363*	-67.3	0.000	0.027	-100, 622
6-months									
Male	113	1.88 (0.950, 3.24)	1.49 (0.562, 3.68)	-0.244 (-1.14, 0.166)	0.491*	20.9	0.026	0.123	-1310, 100
Female	106	1.20 (0.606, 2.15)	1.30 (0.434, 3.92)	-0.136 (-0.564, 1.23)	0.587*	14.7	0.747	0.031	-1080, 100
All	219	1.57 (0.734, 2.72)	1.34 (0.473, 3.79)	-0.194 (-0.747, 0.565)	0.526*	19.0	0.199	0.095	-1050, 100

^A Difference in distance = IMD Distance - IMB Distance^B Spearman's rank correlation coefficient for IMD Distance and IMB Distance; * $p < 0.05$ ^C Percent difference = (Difference in distance / IMB Distance) x 100^D Probability that median percent difference = 0 (One-Sample Wilcoxon Signed Rank Test)^E Correlation coefficient between the IMB Distance and the percent difference^F 95% limits of agreement = median percent difference +/- 2.5th and 97.5th percentiles

Discussion

Children's freedom to play and roam in their neighbourhood without adult supervision continues to decline, which may have a significant impact on their physical and psycho-social health.^[39] Presently, a comprehensive understanding of children's IM is hindered by the lack of a standardised measure which takes into account the complex nature of a child's mobility. In the search for the "ideal" IM definition, online mapping software has been adapted to allow children to explicitly pinpoint where they can and cannot travel independently. The novelty of this study was the use of an innovative online mapping application, VERITAS-IM. Previously explored for use in an adolescent population,^[282] VERITAS-IM was customised to combine survey questionnaires with independent distances and areas to quantify IM in children aged 11-13 years. In addition, the measures derived from VERITAS-IM enabled comparison between destination-based IM (i.e., identifiable locations participants independently roam to) both acutely (7-Days) and chronically (6-Months) with boundary-based IM distance and area (i.e., where participants perceive they are allowed to go). Despite the clear advantages of such a thorough process over conventional questionnaire-based estimates of IM, it is important in the first instance to understand how, if at all, these various measures relate to each other.

The initial comparison between VERITAS-IM-derived measures and IM Index in the present data set revealed some notable similarities. This indicates that the quantifiable measures derived from the VERITAS-IM online mapping application are, to a degree, positively related to a more spatial measure of IM (IM Index). A similar correlation was found in Chapter 3 comparing IM Index with an IM measure derived from Google Maps.^[280] Clearly children who are granted more permissions to go to certain places independently experience a greater perception of overall independent roaming area and distance. The IM Index is survey-based and therefore offers a cost-effective measure suitable for population-based studies and longitudinal research; however, the VERITAS application has an increased capacity to measure children's sense of space and distance beyond specified locations. In addition, contrary to other simple tools, VERITAS-IM, allows the geolocation of children's roaming areas, and therefore it could potentially be used in combination with GIS data to see how IM licences translate to different areas taking into account built environment variables. Furthermore, the amalgamation of VERITAS-IM with GPS as a prompting tool could provide a more objective IM measure.

The use of parental IM licences as a proxy estimate of children's IM has been popular in previous research.^[23,30,49] The IM licences employed in this study were based on two landmark English studies^[23,49] and a previous New Zealand study.^[30] The findings indicate that children who had more liberal parental allowances (IM Licences) had a substantially larger perceived IM area (IMBD Area). Conversely, children who had parental restrictions placed on their movement (with the exception of going out after dark) had significantly smaller perceived roaming areas. These results provide the first quantitative evidence that children with greater parental freedoms experience a significant and meaningful increase in their perceived IM area, which likely translates to an increased physical roaming distance. Given the historical popularity of IM licences, the relationship between this methodology with an online mapping application is important to enable comparability between studies. As with the IM Index, parental licences represent a straightforward measurement technique feasible in large samples. They are also able to overcome the challenges faced when using online mapping procedures in intergenerational comparisons, as the online map may not accurately represent the historical landscapes when adults were children. Despite these advantages, IM licences are still essentially a one-dimensional measure of IM and fail to capture variables which may inhibit or promote children's IM. The online mapping application VERITAS-IM is promising in this regard, as we can go beyond traditional measures that only provide a sense of how much children are allowed to roam independently by actually mapping both perceived extent of permitted areas and actual destinations.

The results also indicated that destination-based estimates of IM area and distance were significantly lower than boundary-based estimates. Given that children's IM is not always destination driven, it is possible that this deviation is a reflection of children's tendency to roam independently without a specified end destination. The perceived IM boundary area that participants identified would therefore encompass areas with no destination markers. In addition, the difference between IMB and IMD estimates was significantly greater for males than it was for females. It is possible that this is a reflection of the substantial evidence that boys are permitted to roam further than girls;^[23,30,48,204,205] subsequently, boys may wander unsupervised to unspecified locations more so than girls. There was very little difference between boundary-based distance and destination-based distance when assessed over six months, which may suggest that children only roam to their maximum IM boundary occasionally (i.e., once or twice in six months).

Given the novelty of the VERITAS-IM measures, this study holds important methodological implications for the field of children's IM. The use of an online mapping application which encapsulates children's unstructured, independent roaming in the neighbourhood as well as travel mode and companionship data, allows for more comprehensive evidence to be collected and may offer a standardised IM measurement technique.^[39] In addition, the development of a measurement technique which can quantify maximum independent roaming distances, locations and boundaries has the potential to significantly further current understanding of the changes in children's unsupervised roaming. Moreover, it is widely acknowledged that children and youth can have difficulties accurately recalling information, which may decrease the reliability and validity of a questionnaire.^[141,283] The interactive nature of the mapping process is likely to have helped facilitate children's recall of local destinations, parental licences and their perceived boundaries. This aligns with the findings of a previous study using a similar version of VERITAS with adolescents.^[282] Furthermore, previous studies have identified the importance of exploring children's perspectives in IM.^[36] It was found that the use of a CAPI enabled collaboration between the researchers and child, allowing them to describe their experiences while being visually prompted by the map. The importance of offering children opportunities to explain their experiences in a number of mediums has been previously highlighted and can assist their recall.^[36,280]

Although there are potential benefits to using an online mapping application to measure children's IM, research in this area is still in its infancy. It is important to note that the data collected through this methodology are still essentially self-reported information. One of the major limitations of the VERITAS-IM mapping application was that each question required a marker to be placed on the map. This may have implied that something was required to be marked at each question. In the instance that a participant did not need a marker placed on the map (for example, there were no locations they were allowed to go to unsupervised), a marker was placed on the home location. Another potential limitation regarding the destination measurements is that the calculated area may have included areas that children could not access, such as oceans. In addition, given the need for a CAPI, investigations with youth using VERITAS-IM or a similar online mapping application may require more time and resource than traditional questionnaire-based methods, and would be more appropriate for small- to medium-sized samples.

Conclusion

In summary, significant similarities between the online mapping application VERITAS-IM and traditional measures of IM were found. The development of a novel IM measure which captures geographically defined data has important methodological implications. There still remains an absence of a standardised IM measure with contingent differences in how IM is defined. Given the complex nature of children's autonomous movement, a mixed method approach combining interactive mapping software with traditional measures in future investigations may significantly help to further understanding in this area.

Chapter 5. Intergenerational Change in Children's Independent Mobility and Active Transport in New Zealand Children and Parents

Preface

It is generally accepted that children's IM and use of active travel modes have decreased from earlier generations. Data presented in this thesis support this notion alongside recent findings from several large population studies.^[24,25,49] Parental concerns for their children's safety are consistently reported to influence the IM children are granted and contribute to the increased use of their motorised transportation. There have not yet been any data comparing changes in children's IM with directly related participants. Given the impact parental perceptions have on children's IM, assessing direct intergenerational change is imperative to understand the extent of the decline. Outcomes from Chapter 3 demonstrated that substantial intergenerational differences in IM exist; the maximum distance children are allowed to travel from home decreased from a mean of 7810m to 2673m between grandparents and children today. However, investigation with a large sample size is required to fully understand this relationship. Measurement techniques refined in Chapters 3 and 4 will be employed in the following study. This investigation will provide the first assessment of generational change in children's IM and active transport with directly related participants, providing an original contribution to the body of knowledge in this area. This chapter has been submitted to the peer-reviewed journal *Health and Place*.

Abstract

Background: Independent mobility (IM) and active transport are two related mechanisms that could increase the amount of physical activity accumulated each day. Previous research has indicated a decline in children's freedom to move in their neighbourhood without adult supervision; however, comparisons between directly related generations are scarce. This study sought to determine the direct generational change in children's IM and active transport in a large sample of New Zealanders.

Methods: A total of 544 children (mean age 12.2 ± 0.6 years) and 500 parents (43.9 ± 5.8 years) participated in the study. Self-reported independent mobility (IM) was measured through IM Licences (parental permission to travel unsupervised) and IM Index (the summed score from a multi-item questionnaire of local destinations travelled to independently). Questions on active transport to and from school, structured activities, and bicycle and vehicle ownership were also included. Parents retrospectively evaluated their IM and active transport patterns as 10-12-year-olds.

Results: Significant generational decreases were observed in IM Index and the majority of parental licences. Compared to their parents, children had significantly lower levels of active transport to (91.8% to 49.3%) and from school (93.2% to 56.9%), greater bicycle and vehicle ownership (1.57 to 2.14 and 2.5 to 3.29, respectively), and significantly more structured activities per week (1.75 to 4.06).

Conclusion: These findings demonstrate a clear generational decline in children's independent mobility and active transport. Greater promotion of active modes of travel and unstructured roaming in the neighbourhood may be an important step in reversing the widespread decreases in children's physical activity.

Introduction

Physical inactivity is inextricably linked with lifestyle disease.^[3,284] The global prevalence of physical inactivity in youth^[3,6] has prompted investigation into behaviours that may promote physical activity during this important developmental period. Recently, children's independent mobility (IM) and its apparent decline in recent years^[15,45] has gained interest as a potential contributor to low levels of physical activity. Children's IM is defined as the ability to play and roam in the neighbourhood without adult supervision, either alone or accompanied by peers.^[13,280] It has been posited that IM provides an important opportunity for physical activity accumulation through spontaneous outdoor play and the use of active modes of transportation, both of which have been linked to a greater probability of achieving recommended levels of physical activity.^[268,285-288]

It is widely acknowledged that a number of psycho-social and environmental factors have contributed to the reduction in children's opportunities for independent exploration of the neighbourhood. A number of potential influences have been suggested, including increased screen time, changes in urban form, lack of social connectedness and a preferred focus on academic and sporting achievement, leading to an increase in structured afterschool activities.^[13,224,225] Parental concerns for their child's safety from fast-moving traffic and the presence of strangers in the streets have consistently been reported as the most significant influences on children's IM.^[29,30,210,225] It has also been regularly reported that parents allow boys greater freedom for autonomous roaming than girls,^[23,30,55,205] although emerging research suggests that the overall decline in children's IM is reducing this sex disparity.^[49,280]

Another recent issue which has the potential to significantly influence children's IM has been the drastic increase in car ownership worldwide. Global rates have risen from approximately 500 million in 1986 to 1.015 billion motor vehicles in 2010, and are predicted to reach 2 billion worldwide by 2030.^[28] Congruently, there has been a severe decrease in the use of walking and cycling as transport (active transport). In children this has been most apparent in the decreased use of active transport to and from school. Many countries have reported findings that the majority of youth are driven to school including, Australia,^[234] Canada,^[235] England and Norway.^[35] New Zealand is not immune; more than half of children's transport to and from school is by car,^[289] and overall walking in children aged 5-14 has decreased from an average of two hours and ten

minutes per week in 1989/1990 to just under an hour and ten minutes per week in 2006/2009.^[218] While it is likely there is a relationship between active transport and children's IM, this remains largely unknown.

A number of investigations have attempted to quantify the decrease in children's IM. In England considerable decreases in children's IM licences (parental permission to be on their own) have been noted over last 40 years.^[49] Specifically, the proportion of children aged 7-11 years travelling home from school without adult supervision was found to have dropped from 86% in 1971 to 25% in 2010.^[49] Similarly, a recent Australian study investigating children's mobility over a 12-year period found the proportion of 8-13-year-olds travelling home from school alone dropped from 68% to 31%.^[24] Research conducted in Norway,^[290] Italy,^[206] Finland,^[25] and in other regions of England^[216] have shown comparable results.

Despite the accumulating research in this area, there remains a paucity of research exploring differences between IM across generations with directly related participants. Exploring intergenerational change in IM is crucial to accurately assess the extent of the decline, particularly given the influence of parental perceptions. Chapter 3 assessed differences in IM across three related generations (children, parents and grandparents). IM was measured through parental licences, allowances to go to certain locations (IM Index), and maximum independent roaming distance. Substantial intergenerational decreases were observed in all measures.^[280] In Australia, changes in neighbourhood use have been assessed between children aged 5-12 years old and their parents.^[238] While this investigation did not specifically explore changes in IM, the difference in play-based activities was clearly seen, with children pursuing considerably more television- and computer-based interests than their parents.

In addition to a lack of direct intergenerational comparisons, there have been inconsistencies in the conceptual definition and measurement of IM, limiting comparisons between countries even further. While parental licences are a traditional measure of IM,^[15,23,30,49,291] there are disparities in the precise distinction of a parental IM licence, and further elucidation around the level of supervision is required.^[280] Similarly, while active transport to and from school has been a popular measure,^[227,245,248,249] it is possible that this journey is not undertaken independently and may not be a sufficient measure of IM on its own.^[24] Nonetheless, as a potential influencer of children's IM, knowledge of how active transport has declined generationally may offer further insight into

the extent of this issue. Emergent investigations using location-based parental licences to form an IM Index have also been used; this has been shown to be correlated with more geographical IM measures via online mapping (Chapter 3).^[280] It has lately been suggested that a mixed methods approach may provide a more in-depth assessment of IM.^[39,280] It is possible that to gain a comprehensive understanding of how IM has changed over time, comparisons among directly related generations using a number of interrelated IM measures is required. Therefore, the aim of this study was to assess direct intergenerational change in IM within a large sample of children and their parents using a number of common IM indicators.

Methods

Participants

A cross-sectional survey was completed across four intermediate schools (school years 7-8) in Auckland, New Zealand in 2013. Schools were purposively selected to obtain participants from a range of socio-demographic and ethnic backgrounds. Two schools had the highest socioeconomic decile rating (10), while the third had a decile rating of 6, and the fourth a decile rating of 3. Written informed consent from parents and assent from children were required for each dyad prior to being involved in the study. Ethical approval was obtained from the host institution's ethics committee AUTC (Refer to Appendix B).

All children and their parents from each school were invited to participate in the study. The children were given an information sheet, a questionnaire, and consent and assent forms to take home. Participants who gave assent (children) and consent (parents) returned the completed questionnaire and forms to school. Refer to appendices for both the child (Appendix D) and parent (Appendix E) questionnaires.

Measures

Family and demographic

Comprehensive demographic data were collected through the parent questionnaire, including year of the child's birth, sex, ethnicity, and the number of children in the family. The current number of vehicles and bicycles in the household were reported and parents also recalled the ownership number of both bicycles and vehicles when they were 10-12 years old. The parents

were invited to fill in their level of education and had five options to select from: finished primary school, finished high school, obtained university entrance, completed an apprenticeship or diploma, or completed university. Demographic data were also collected through the child's questionnaire (birth year, sex, number of siblings and ethnicity).

Active Transport

Participants reported their mode of transport to and from school. They were given five options: walk, car, cycle, bus, scooter or other. These options were categorised into active (walk, cycle or scooter) and non-active (bus or car). Parents reported their usual travel mode to and from school as 10-12-year-olds.

Independent Mobility

Questions that formed three measures of IM were included in both the child and parent questionnaires. The child participants reported their current IM allowances and mobility and parents recalled their personal experiences as a 10-12-year-old.

IM Licence

Parental licence questions (IM Licence) were replicated from those used in earlier studies.^[23,30,49] Participants were asked if they were allowed to do the following either by themselves or with friends (without an adult): travel to and from school, cross main roads, cycle main roads, catch a bus/train, or go out after dark. Participants were given the option of responding with either yes, no or not sure.

IM Index

Participants' permission to go to certain locations in their neighbourhood was assessed using a questionnaire previously used in another international study,^[43] the responses to which formed a ranked index, trialed in a recent pilot study.^[280] Specifically, participants were asked "how often are you allowed to go to the following places on your own or with friends (without an adult)?" For each location (local shops, big shopping centre, park, sports centre, swimming pool, library, school, cinema, friend's house, other outdoor places [beach, river, bush], bus stop or train station and local streets) participants were given the following scale to choose from: never, sometimes,

often, or always. Participants were given an additional option of “I do not go there” for locations that are not available in the area. A rank of either never (0), sometimes (1), often (2) or always (3) was assigned and then summed to give a total score. The summed total was divided by the number of places the participant went to (excluding the “I do not go there” responses), which gave an overall IM Index.^[280]

Data Analysis

The six parental licenses and active transport practices were compared between generations and sexes via generalised linear models using a binomial distribution with a logit link function. This technique enables the odds of a parental license and the odds of active transport to/from school to be evaluated between each generation and sex group while allowing for the paired nature of parent/child dyads. Models were presented unadjusted (generation and sex separately) and adjusted (generation and sex together). Associations of the number of structured activities, the number of bicycles owned, the number of vehicles owned, and IM Index with generational and sex groups (and their interaction) was assessed via generalised linear models using a normal distribution with an identity link. Statistical significance was set at $p < 0.05$, and all analyses were conducted using IBM SPSS Statistics (V. 20).

Results

A total of 2030 invitations were sent home with students of participating schools. Of these, 544 children (257 male and 272 female; mean age 12.2 ± 0.6 years) and 500 parents (118 male and 373 female; mean age 43.9 ± 5.8 years) completed the questionnaire (500 dyads of child-parent matched pairs). The ethnic distribution of child participants was European ($n=368$, 76%), Asian ($n=50$, 10.4%), Maori/Pacific Island ($n=41$, 7.5%), and Other ($n=21$, 4.4%). Parental ethnicity was European ($n=359$, 77%), Asian ($n=53$, 11.3%), Maori/Pacific Island ($n=41$, 8.8%), and Other ($n=14$, 3%).

Table 5-1 shows parental licenses and active transport practices compared by generational group. The odds of parents being granted permission to travel to school unsupervised was twice that granted to children today (OR 2.18 95% CI: 1.31, 3.63). Parents were also twice as likely to be allowed to cross main roads than children (OR 2.26 95% CI: 1.34, 3.71). Compared to children,

parents were five times more likely to be granted permission to cycle main roads (OR 4.99 95% CI: 3.62, 6.87). In addition, parents were three times more likely to be allowed out after dark compared to children today (OR 3.05 95% CI: 2.12, 4.38). All odds were statistically significant ($p < 0.05$). While slightly more parents were allow to travel from school unsupervised and use public transport, these differences were not statistically significant.

In regard to absolute findings, the majority of parent participants were permitted to travel to and from school (94.4% and 98.3%, respectively), cross main roads (93.9%), cycle main roads (76.1%) and travel on buses/trains unsupervised (67.0%). Similarly, the majority of child participants still reported permission to travel to and from school, cross main roads, and travel on buses/trains (62.0%-91.6%). In contrast to parents, a minority of children were permitted to cycle main roads (43.2%). Few parents were permitted out after dark (29.0%); however, this was double the number of children (14.2%). The majority of parents took active transport modes to school (91.8%) and from school (93.2%), compared to children (49.3% and 56.9%, respectively) with parents having an adjusted odds ratio of 11.9 and 11.4.

Table 5-2 displays the comparisons in parental licenses and active transport by sex. More males than females were granted parental licences (in all variables), and permission and to actively travel to and from school. Differences between males and females were significant when adjusted by generation. Males were 1.3 times more likely to be allowed to come home from school along (OR 1.33 95% CI: 0.76, 2.32), 1.5 times more likely to be allowed to cross main roads (OR 1.58 95% CI: 0.96, 2.61), 1.8 times more likely to cycle main roads (OR 1.78 95% CI: 1.28, 2.47) and 1.9 times more likely to be allow out after dark (OR 1.9 95% CI: 1.34, 2.74). In regard to active transport males were 1.4 times more likely to use active modes of travel home from school than females (OR 1.42 95% CI: 1.02, 1.98).

Table 5-1. Associations of parental licenses and active transport with generational group.

	No. of Participants (%)		Odds ratio (95% CI)	
	Yes	No	Unadjusted	Adjusted [†]
Allowed to travel to school unsupervised				
Child	446 (89.4%)	53 (10.6%)	1.00	1.00
Adult	422 (94.4%)	25 (5.6%)	2.01 (1.22, 3.29)*	2.18 (1.31, 3.63)*
Allowed to travel from school unsupervised				
Child	457 (91.6%)	42 (8.4%)	1.00	1.00
Adult	426 (98.3%)	21 (4.7%)	1.86 (1.08, 3.20)	2.01 (1.15, 3.50)
Allowed to cross main roads unsupervised				
Child	423 (88.5%)	55 (11.5%)	1.00	1.00
Adult	418 (93.9%)	27 (6.1%)	2.01 (1.24, 3.26)*	2.26 (1.34, 3.71)*
Allowed to cycle on main roads unsupervised				
Child	181 (43.2%)	238 (56.8%)	1.00	1.00
Adult	319 (76.1%)	100 (23.9%)	4.20 (3.12, 5.64)*	4.99 (3.62, 6.87)*
Allowed to ride a bus or train unsupervised				
Child	266 (62.4%)	160 (37.6%)	1.00	1.00
Adult	264 (67.0%)	130 (33.0%)	1.22 (0.92, 1.63)	1.28 (0.95, 1.72)
Allowed to be out after dark unsupervised				
Child	62 (14.2%)	375 (85.8%)	1.00	1.00
Adult	124 (29.7%)	293 (70.3%)	2.60 (1.82, 3.60)*	3.05 (2.12, 4.38)*
Actively travel to school				
Child	257 (49.3%)	264 (50.7%)	1.00	1.00
Adult	437 (91.8%)	39 (8.2%)	11.5 (7.94, 16.7)*	11.9 (8.15, 17.4)*
Actively travel from school				
Child	291 (56.9%)	220 (43.1%)	1.00	1.00
Adult	442 (93.2%)	32 (6.8%)	10.4 (6.99, 15.6)*	11.4 (7.57, 17.2)*

*Significantly different from reference group ($p < 0.05$).

†Adjusted for sex.

Table 5-2. Associations of parental licenses and active transport with sex.

	No. of Participants (%)		Odds ratio (95% CI)	
	Yes	No	Unadjusted	Adjusted [†]
Allowed to travel to school unsupervised				
Female	543 (91.4%)	51 (8.6%)	1.00	1.00
Male	324 (92.3%)	27 (7.7%)	1.19 (0.70, 2.03)	1.39 (0.84, 2.30)
Allowed to travel from school unsupervised				
Female	554 (93.1%)	41 (6.9%)	1.00	1.00
Male	328 (93.7%)	22 (6.3%)	1.14 (0.64, 2.03)	1.33 (0.76, 2.32)*
Allowed to cross main roads unsupervised				
Female	527 (90.4%)	56 (9.6%)	1.00	1.00
Male	313 (92.3%)	26 (7.7%)	1.23 (0.73, 2.08)	1.58 (0.96, 2.61)*
Allowed to cycle on main roads unsupervised				
Female	311 (59.1%)	215 (40.9%)	1.00	1.00
Male	189 (60.8%)	122 (39.2%)	1.08 (0.80, 1.45)	1.78 (1.28, 2.47)*
Allowed to ride a bus or train unsupervised				
Female	331 (63.5%)	190 (36.5%)	1.00	1.00
Male	198 (66.4%)	100 (33.6%)	1.14 (0.84, 1.53)	1.21 (0.89, 1.65)
Allowed to be out after dark unsupervised				
Female	107 (19.6%)	438 (80.4%)	1.00	1.00
Male	79 (25.6%)	230 (74.4%)	1.40 (0.10, 1.20)	1.91 (1.34, 2.74)*
Actively travel to school				
Female	460 (72.9%)	171 (27.1%)	1.00	1.00
Male	234 (64.1%)	131 (35.9%)	0.69 (0.48, 0.98)	1.16 (0.84, 1.59)
Actively travel from school				
Female	474 (76.0%)	150 (24.0%)	1.00	1.00
Male	259 (71.9%)	101 (28.1%)	0.80 (0.54, 1.19)	1.42 (1.02, 1.98)*

*Significantly different from reference group ($p < 0.05$).[†]Adjusted for generational group.

Figure 5-1 shows the generational differences in IM Index, structured activities, and the number of bicycles and vehicles per household. There were no significant effects of ethnicity or education level and these factors were excluded from the analyses. There was a significant decrease in IM Index scores between parents and children for both males (2.05-1.53) and females (1.77-1.40). Boys experienced greater IM Index scores for both generations. In addition, the average number of cars per household for parents was 1.6 (95% CI: 1.50, 1.65), which increased to an average 2.1 for children (95% CI: 2.06, 2.22). Bike ownership also increased generationally with adults having an average of 2.5 bikes (95% CI: 2.37, 2.64) and children having 3.29 (95% CI: 3.05, 3.54). The average number of structured activities for adults was 1.75 (95% CI: 1.62, 1.89), which increased in children to an average number of 4.06 activities (95% CI: 3.89, 4.25). Boys were involved in more structured activities for both children and adults. There was no interaction between generation and sex for any of the outcome variables.

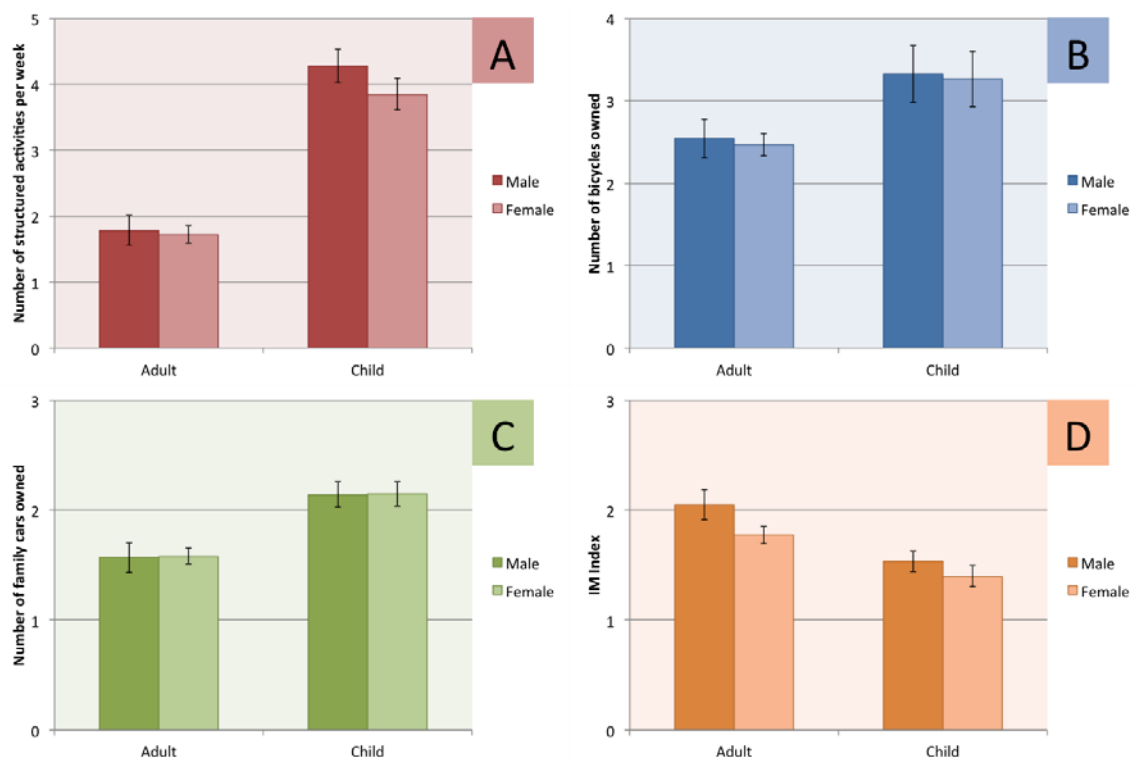


Figure 5-1. Generational differences in the number of structured activities (A), the number of bicycles owned (B), the number of family cars owned (C), and IM Index (D) grouped according to sex.

Discussion

There is currently some evidence to suggest that children's ability to play and roam in the neighbourhood without adult supervision has decreased drastically from previous generations.^[23,26,30,48] Accurate comparisons between countries and studies has previously been hindered by a lack of research exploring intergenerational differences and inconsistencies with how IM has been defined and measured. It is believed that this is one of the first studies to investigate generational change in IM across a large sample of directly related participants using a number of measurement techniques.

The findings indicate that there were substantial intergenerational differences in children's IM compared to their parents. Significant differences in IM Index data between adults and children were observed, which corresponds with the results of Chapter 3.^[280] There were also significant generational decreases in a number of parental licences. Specifically, the results indicate that parental licenses to travel unsupervised to school, cross and cycle main roads, and go out after dark all significantly declined from parents to children. A recent study in Australia investigating IM changes in 8-13-year-olds found declines in the proportion of children allowed to travel to and from school unsupervised and allowed to go on a bus alone.^[24] Similarly, in Finland declines were observed in almost identical mobility licences for children aged 7-15 years old.^[25] While direct generational change was not determined in these studies, the findings do align to suggest that children today experience much less freedom to play and roam unsupervised than earlier generations.

It was apparent males were granted substantially more liberty compared to females and these differences persisted into today's generation. Previously, literature has consistently reported similar sex disparities.^[23,30,48,205] There are a number of social perceptions that may underpin these findings, including parents deeming boys more capable of handling risky situations^[29] and girls being expected to contribute to the household more than boys.^[37] In addition, there is the social norm that girls do not wish to play outside, rather preferring more indoor based pursuits^[22]. However, it could be inferred that the latter is not likely given the increased "rules" in which to prevent girls roaming unsupervised. As children's IM is rapidly declining, it is possible that the sex gap will decrease. Recent research has alluded to this, including the work in Chapter 3 however; that study was conducted with a small sample size. Potentially, the evidence in this study

highlights a greater need to focus on girls' IM in future interventions. However, it is unclear whether this would redress the inequity or if these perspectives are so firmly embedded that they cannot be changed.

The data do suggest, however, that despite greater restrictions in parental licences between generations, the majority of the child participants were still granted a number of licences including being allowed to travel to and from school, cross main roads, and travel on buses/trains (62%-91.6%). These findings are similar to a previous New Zealand study,^[30] which used almost identical parental licences to investigate children's IM in another large city (Christchurch). International investigations of children's parental IM licences have to date reported mixed findings. Studies in England,^[23] Australia,^[24] Norway^[290] and Italy^[206] have indicated only a small percentage of children are granted parental licences,^[23,24,206,290] whereas more recent studies in Germany^[23] and Finland^[25] have reported findings similar to ours in that the majority of participants still experience considerable mobility licences.^[25,291] Recently, a large comparability study comparing children's IM licenses across 16 countries found significant disparities between countries.^[291] It is possible that the variation among studies is a reflection of inconsistencies in the term unsupervised, with some studies only defining IM as either the presence or absence of an adult^[280] without considering the companionship of siblings or peers, which has been shown to influence parental permission for allowing IM.^[210] The higher parental licences observed in this study may have been as a result of participants including licences granted on the proviso of being with a group of friends or siblings. Moreover, diversity in the built environment and geographical landscapes may explain the variation between countries; collecting these types of data might therefore be worthwhile in future studies.

There is an extensive global discourse on the reasons for the trending decline in children's IM. Fundamental changes in suburban form, cultural ideologies and technological developments have created significant barriers for children experiencing free range autonomous roaming in their neighbourhoods.^[26,32,55,292] These findings provide supporting evidence to some of these proposed reasons driving the decline in children's IM. The dominance of private car ownership and the subsequent reliance on motor vehicles for transport has vastly impacted children's IM.^[55] The increase in car ownership was evident in this study, with households now having nearly double the number of vehicles from one generation earlier. In parallel with this trend, declining

rates of active school travel have previously been highlighted.^[35,245,247,293] The findings of this study are consistent with this; the number of children using active travel modes to and from school dropped by nearly half from parents to children. It was concerning to see the significant divide in this between generations, with the odds of active travel 11 times greater in the parent generation than in the children. Low levels of active school travel in New Zealand have previously been found in other cross-sectional studies^[36,222,285] as well as in the most recent National Travel Survey.^[294]

It is interesting to note that parents had higher odds of answering yes to both “are you allowed to travel to school unsupervised” and “actively travel to school”. It is logical that the two are related: those that are allowed to travel to and from school on their own are almost certain to use active transport to do so (i.e., walking or cycling). It was also interesting to observe the significant increase in the number of structured organised activities, a trend that has also been cited in other investigations.^[226,295] A social emphasis away from unstructured play to sporting success^[224] has seen the rise in structured after-school activities. It is likely that the subsequent “trip-chaining” to numerous organised activities has decreased children’s use of active mobility.

Another notable outcome was the significant decline in the permission to cycle main roads, with less than half of the child participants (43.2%) being granted this permission compared to their parents (76.1%). Although the odds of being allowed to cycle main roads were four times greater in adults compared with children, children had a much higher bicycle ownership. Widespread re-engagement in cycling as transport may be a way to provide children with an active, independent mode of transport to school, and to promote active transport to activities that are located further than the distance deemed reasonable for children to walk.^[296]

The significant decline in children’s IM from just one generation earlier is disquieting. The long term implications of children experiencing severe restrictions on their autonomous roaming remains largely unknown. Evidence has begun to emerge suggesting a relationship between IM and physical activity,^[43,44,277,281] and the relationship between active travel to school and accumulation of daily physical activity levels has been well documented.^[16,297] The findings from this study would suggest a need for health promotion strategies and public policies at individual, community and government levels supporting parents and children to decrease motorised travel and encourage free roaming in the neighbourhood.^[291,298]

Strengths/Limitations

This study was novel in its exploration of generational changes in IM by using directly related participants. In addition, participants from a broad range of socio-economic areas were included, which increases the generalisability of the findings.^[24] The other major strength of the study was the use of several measurement techniques simultaneously; previously, inconsistent IM definitions and measurement protocols have limited our understanding of the extent to which children's IM has declined.^[39,280] The measures utilised in this study have been correlated with physical roaming distances measured via online mapping and acknowledged for feasible application with a large population sample.^[280]

It is important to note that these measures are essentially self reported, which may result in recall bias. Additionally, the IM measurement techniques in this study are still largely one dimensional. This means that the data may not take into account other secondary influences on parental allowances for children to travel and roam in the neighbourhood, such as the utility of mobile phones to facilitate children's independent roaming while maintaining a level of indirect supervision.^[239]

Conclusion

In summary, the findings from this study clearly indicate a considerable decrease in children's IM and active transport between generations, with boys consistently demonstrating greater IM indicators than girls. The use of a combination of IM measurement techniques with directly related participants enabled a more comprehensive understanding of this decline than previously possible. Health promotion strategies to encourage active transport modes and independent roaming behaviours are now needed to arrest this trend, thereby providing more opportunities for children to be active and enhance their psycho-social development.

Chapter 6. Associations between Children's Independent Mobility, Physical Activity and Sedentary Behaviour

Preface

Outcomes from Chapter 5 clearly showed the intergenerational declines in children's IM and active transport modes. Parents were twice as likely to be granted licences to travel to school, cross main roads and go out after dark unsupervised. There was an absolute decrease from 76.0%-43.2% between parents and children being allowed to cycle main roads unsupervised. IM Index also declined significantly between parents and children for both males (2.05-1.53) and females (1.77-1.40). In addition, there was a drastic decline in active travel to and from school between parents (91.8% and 93.2%, respectively) and children (49.0% and 59.9%, respectively).

These findings are in alignment with previous global research. It is highly probable that there is an association between children's declining IM and low levels of activity present in youth today. Systematic review of the literature in Chapter 2 indicated that while there is some evidence to support this relationship, further investigation is required using robust measures of children's IM. In the following chapter, geographically defined IM measures (IMB Area and Distance) developed and tested in Chapter 4 were compared with objectively measured physical activity and sedentary time. This chapter has been prepared for journal publication and will contribute significantly to understanding children's physically active behaviours.

Abstract

Background: Children's independent mobility (IM) has decreased from earlier generations and is a possible contributing factor to low levels of physical activity in youth today. There is currently limited evidence exploring this relationship. The objective of this study was to investigate the relationship between comprehensive measures of children's IM, sedentary behaviour and levels of light, moderate and vigorous physical activity.

Methods: Data were collected for 219 children (median age 12.0 years old). IM roaming areas and distance (IMB Area and IMB Distance) were derived from VERITAS-IM, an online mapping application, and compared to minutes of light, moderate-to-vigorous physical activity (MVPA), step counts and sedentary time.

Results: Children with the highest IMB Distance and IMB Area took part in 15.4 minutes and 16.4 minutes, respectively, more MVPA per day than those with the lowest IM. IMB Distance was significantly associated with light ($p=0.02$), moderate ($p=0.04$), and total MVPA ($p=0.03$). There were no significant associations between IMB Area and any activity intensity. Both IMB Distance and IMB Area were significantly associated with sedentary time ($p=0.03$ and $p=0.02$, respectively). Those with the lowest IMB Distance and IMB Area (lowest quartile) spent 36.1 minutes and 54.5 minutes, respectively, more a day being sedentary than those with the highest IM.

Conclusion: This study demonstrates the contribution children's IM can have on daily activity levels and sedentary time. Developing public policy and environments to encourage children's independent free roaming in the local sphere is important.

Introduction

There is substantial evidence to demonstrate the importance of physical activity on children's health.^[3] Children who are physically active benefit from improved bone strength,^[64] are more likely to maintain a healthy weight,^[84] develop fundamental motor skills^[17] and have reduced risk for numerous non-communicable diseases.^[299] However, globally children's physical activity levels are low in comparison to recommended activity guidelines for health.^[3] As patterns of physical activity established during childhood are likely to be important predictors of activity in later life,^[8,9] investigation into behaviours inhibiting or promoting physical activity in this stage of development is crucial.

Children's ability to play and travel independently in their neighbourhood either alone or accompanied by peers (without the presence of an adult) is defined as independent mobility (IM).^[13] Once a natural part of children's everyday lives, there is consistent evidence to indicate a trending downward decline in children's IM from previous generations. Previously in Chapter 3, a study with matching child-parent-grandparent triads, found decreases in a range of IM indicators.^[280] For example, only one child was permitted the same completely unrestricted licence to roam and travel as their grandparents experienced. In Chapter 5, a subsequent study also comparing intergenerational differences in 500 New Zealand children and their parents also found significant declines in IM. Parents were twice as likely to be allowed to cross main roads than children, and five times more likely to be granted permission to cycle main roads. In addition there was a significant decrease in IM Index scores between parents and children for both males (2.05-1.53) and females (1.77-1.40). Similarly, in a recent Australian study decreases were found in the number of children allowed to go home from school alone from 60% to 31% between 1991 and 2012.^[24]

IM provides children with numerous occasions to naturally accumulate daily recommended levels of physical activity through outdoor play and transport-related activity (active transport). Meeting recommended levels of physical activity in children (60 minutes of MVPA per day)^[3] has been associated with both of these domains.^[268,270,285,286] In addition, it is during the time periods after school and on weekends that children are mostly likely to partake in independent activities. Emerging evidence suggests, however, that it is at both of these time points that children with low overall physical activity levels are the least active.^[136,158,160] It has also been reported that girls

who spent more time after school without adult supervision were more active than those with supervision.^[300] It is highly possible that children with restricted IM experience lower physical activity levels than those with increased autonomous roaming.

Presently the relationship between children's physical activity and IM has only been explored in a few studies.^[16] In the United Kingdom, 10-12-year-old children who experienced greater allowances to roam to certain locations on their own (or with peers) were found to have higher levels of objectively measured physical activity than those who had less freedom.^[43] Likewise in Canada, children of the same age (10-12 years) who were never allowed out without an adult experienced lower, objectively measured, moderate-to-vigorous physical activity than those with higher levels of IM.^[15] In this study, particular differences were found in the after-school period and on weekends, whereby those with greater overall IM had better activity profiles during these time points. Similar positive associations have been observed in more recent English^[271] and Australian^[243] studies as well as in Portugal.^[45] Conversely, in Australia associations were only found with active transport modes in children aged 8-13 and no differences were observed in objectively measured physical activity.^[249]

Sedentary behaviour is now recognised as a stand-alone risk factor for numerous chronic diseases and is associated with sleep disturbances,^[172] hypertension^[175] and obesity^[95,177,178] in children. High global levels of sedentary behaviour in children are a significant public health concern which has stimulated investigations into possible associated behaviours, independent from physical activity activity.^[7] Although some IM studies have explored activity levels with accelerometers, only a small number have reported estimates of sedentary time^[15,264] and findings are so far inconclusive. In Canada it was found that for girls, lower levels of IM resulted in less time being sedentary,^[15] yet in the United Kingdom, it was found that IM made no difference to levels of inactivity.^[264] It is clear there is currently a paucity of research in this area^[16] and it remains unknown if IM has an impact on children's physical inactivity levels.

A fundamental issue in IM research to date has been the absence of a standardised measurement technique.^[39] Extensive critique of previous investigations in this area revealed significant variation between the measures of IM used across each study. Children's unsupervised roaming has been assessed via self or proxy reports of parental permission to go to certain destination-based locations,^[43,45,249] ability to go out in the neighbourhood alone,^[15,264,271] and allowances to

walk alone near home.^[44,243] Advances in the field have enabled more sensitive and specific measures of IM to be collected, including activity spaces^[46] and maximum roaming distances^[280] via online mapping techniques. Although this is an emerging field, to date no research has employed online mapping methodology in relation to physical activity.

It is apparent that the relationship between IM, physical activity and sedentary behaviour requires further investigation, and more robust evidence is required for these associations to be empirically established. It has been proposed that interactive mapping may produce a rich data set necessary to understand the complex nature of children's IM. The aim of this study was to compare objectively measured physical activity and sedentary time with geographically defined IM via an online mapping application.

Methodology

Participants

All children from three intermediate (school years 7-8) schools in the Auckland region were invited to participate in the cross-sectional study during 2013. Schools were purposively selected to obtain participants from a range of socio-demographic and ethnic backgrounds. One school had the highest socioeconomic decile rating (10), the second had a decile rating of 6, and the third school had a decile rating of 3. All children were provided with an information sheet, and consent and assent forms to take home. Only those who gave written assent and their parent or guardian provided written consent were selected to participate in the study. Ethical approval for the study protocol was obtained from the host institute's Ethics Committee, AUTECH (Refer to Appendix B).

Procedure and Instruments

Data collection took place at a designated time during school hours. Under the supervision of a research assistant, children completed a computer-assisted personal interview (CAPI). The purpose of the CAPI was to collect geographically defined data on children's IM through an online mapping programme, VERITAS-IM. The research assistant explained the protocol of the CAPI, which was conducted on a laptop computer connected to the school's wireless local area network (WLAN) and took each participant approximately 20 minutes to complete.

VERITAS-IM was developed from the original VERITAS application (VERITAS-RECORD)^[46] and specifically customised to capture children's IM. The programme consists of a sequential series of interactive maps, embedded within Google Maps functionality and tenanted with key questions regarding children's spatial mobility. The questions have been described in detail previously (refer to Chapter 4). Briefly, participants initially located their primary home residence, followed by locations where they had been independently mobile (either by themselves or with friends, in the absence of an adult) in the previous six months and last seven days. Additional information on transport mode, frequency and companionship to each location was also collected. Using the previously identified locations as a guide, participants then drew a polygon shape around the area in their neighbourhood which they perceived as their maximum independent roaming area.

All geospatial data were saved to a secure server and then imported into ArcGIS 10.1 (ESRI, Redlands, CA, USA). The datum were visually inspected for any errors and then the IM measures were calculated (displayed in Figure 6-1). IM Boundary Area (IMB Area) was calculated as the area inside the perceived IM boundary polygon. IM Boundary Distance (IMB Distance) was calculated as the Euclidean distance (i.e., as the crow flies) from home residence to the furthest point in the perceived IM boundary polygon. To determine if this was the most ecologically robust measure of children's IM derived from the VERITAS application, comprehensive statistical comparisons were conducted with other measures derived from VERITAS-IM (maximum roaming distances and location-based IM area) and two more traditional measures of IM (parental licences and allowances to go to certain locations independently; IM Index) (Chapter 4).

To objectively measure physical activity, children were asked to wear an activity monitor over seven consecutive days (Monday through to Sunday) to capture activity at 15-second intervals during the week and weekend. The research assistant explained the protocol of the activity monitor and children were fitted with Actical omnidirectional accelerometers (Mini Mitter Co., Inc., Bend OR), which have been shown to provide a reliable estimate of children's physical activity.^[296] The accelerometers were mounted onto a thin elastic belt worn around the participant's hips during all waking periods (except in the shower or during water activities). Each child was also given a compliance diary and showed how to complete this in order to estimate non-wear times. A week later, the research assistant returned to the schools to collect the activity monitors and compliance diaries.

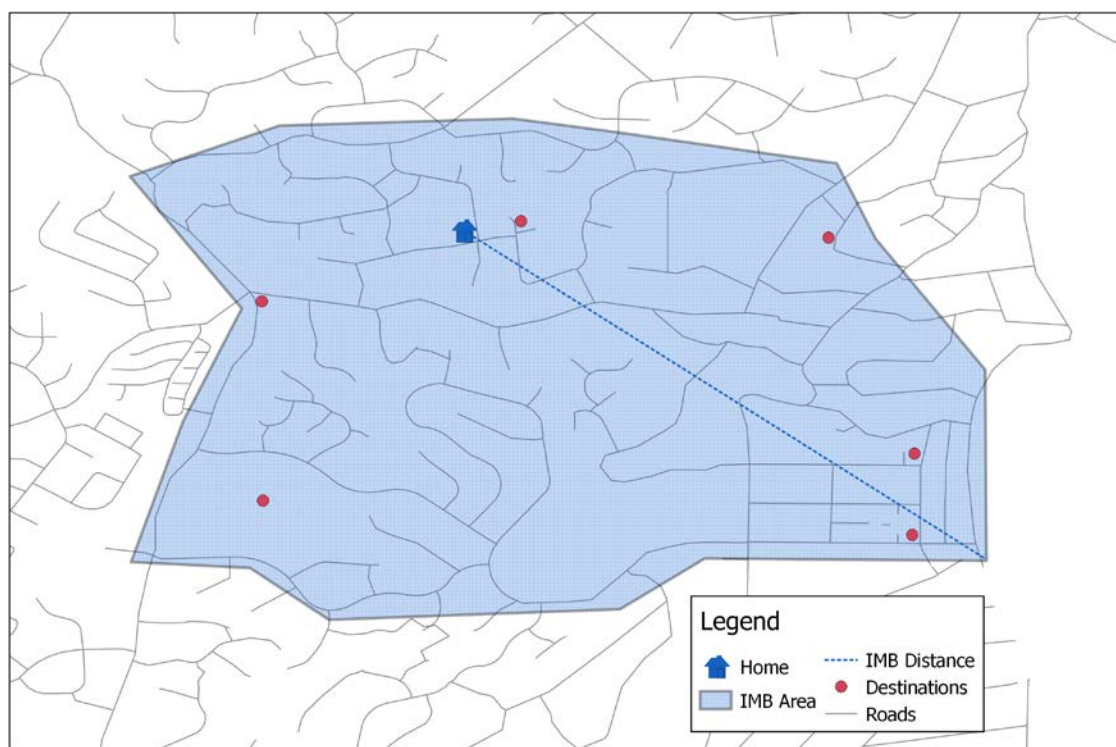


Figure 6-1. VERITAS-IM derived IM Boundary Area (IMB Area) and IM Boundary Distance (IMB Distance)

Physical Activity Data Cleaning/Inclusion Criteria

At the end of each collection period, accelerometer data was downloaded before being checked manually for wear compliance. Sustained 60-minute periods of zero counts defined non-wear time, and total “missing” counts for those periods represented overall non-wear time.^[301] A valid day was defined as >10 hours of wear time per day (after non-wear time was removed). Data from children with at least four valid measurement days (including a minimum of one weekend day) were retained for further analysis, as these are commonly used protocols.^[41,302] Minutes per day of MVPA were calculated using 15-second epochs and threshold counts of <100 sedentary, 101-1499 light, 1500-6499 moderate and 6500 vigorous.^[303] All accelerometer data, including step counts, were processed in SAS v9.4 with the ACCEL+ data analysis support tool.^[304]

Data Analysis

IMB Area and Distance were categorised into four quartiles ranging from low (I) to high (IV). Observation of the descriptive statistics revealed that the IM variables were not normally distributed, and subsequently the non-parametric Mann-Whitney U test was used to evaluate

differences between sexes. Associations between the quartiles of IMB Area/Distance and physical activity intensity, sedentary time, and step counts were quantified using generalised linear models (adjusted for age and sex). Statistical significance was set at $p < 0.05$, and all analyses were conducted using IBM SPSS Statistics (V. 20).

Results

Descriptive data are presented in Table 6-1 for 219 children (113 male and 106 female) with a median age of 12 years (interquartile range [IQR] 12.0,13.0). There were significant differences between sexes for both IMB Distance and Area; boys had significantly higher IMB Distance and IMB Area than girls. In regard to physical activity, the median time boys spent in MVPA per day (42.8 minutes, IQR 21.3, 67.7) was significantly higher than girls (35.5 minutes, IQR 24.0, 61.4). Participants were inactive for an average of 7.81 hours per day and there were no significant differences between sexes in sedentary time or levels of activity.

Table 6-1. Independent mobility and physical activity descriptive statistics

	Boys		Girls		All	
	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)
Age (years)	113	12.0 (12.0, 13.0)	106	12.0 (12.0, 13.0)	219	12.0 (12.0, 13.0)
IM Distance (km)	113	1.88 (0.950, 3.24)	106	1.20 (0.606, 2.15)*	219	1.57 (0.734, 2.72)
IM Area (km ²)	113	2.08 (0.404, 5.88)	106	0.639 (0.180, 2.46)*	219	1.26 (0.303, 4.53)
Sedentary (min/day)	79	478 (414, 535)	76	479 (433, 542)	155	479 (421, 540)
Light PA (min/day)	79	253 (200, 287)	76	255 (222, 298)	155	255 (208, 291)
Moderate PA (min/day)	79	41.4 (21.3, 66.9)	76	34.8 (23.0, 61.3)	155	39.6 (22.5, 63.2)
Vigorous PA (min/day)	79	0 (0, 0)	76	0 (0, 0.170)	155	0 (0, 0)
MVPA (min/day)	79	42.8 (21.3, 67.7)	76	35.5 (24.0, 61.4)	155	39.8 (22.5, 64.2)
Step count (steps/day)	75	12,300 (8,970, 15,200)	69	11,600 (7,590, 14,600)	144	11,900 (8,220, 15,000)

*Significantly different from boys ($p < 0.05$).

Figures 6-2 and 6-3 display associations between measures of activity (daily time spent in light activity, MVPA, sedentary time and step counts) with IMB Distance (Figure 6-2) and IMB Area (Figure 6-3). A gradual increase in time spent in each physical activity intensity can be observed across the IM quartiles. Those with the highest IMB Distance (fourth quartile) and IMB Area took part in 15.42 minutes and 16.36 minutes, respectively, more MVPA per day than those in the lowest quartile. IMB Distance was significantly associated with light ($p = 0.02$), moderate ($p = 0.04$), and total MVPA ($p = 0.03$). There were no significant associations between IMB Area and light ($p = 0.08$), moderate ($p = 0.09$), and total MVPA ($p = 0.09$), although this is suggestive.

Conversely, both IMB Distance and IMB Area were significantly associated with sedentary time ($p = 0.03$ and $p = 0.02$, respectively). Those with the lowest IMB Distance and IMB Area (lowest quartile) spent 36.1 minutes and 54.5 minutes, respectively, more a day being sedentary than those with the highest IMB Distance and IMB Area. Similarly, there was a steady increase in step counts across the quartiles for both IM measures; however, this only statistically significant for IMB Distance ($p = 0.04$). There were no interactions between age or sex with any associations.

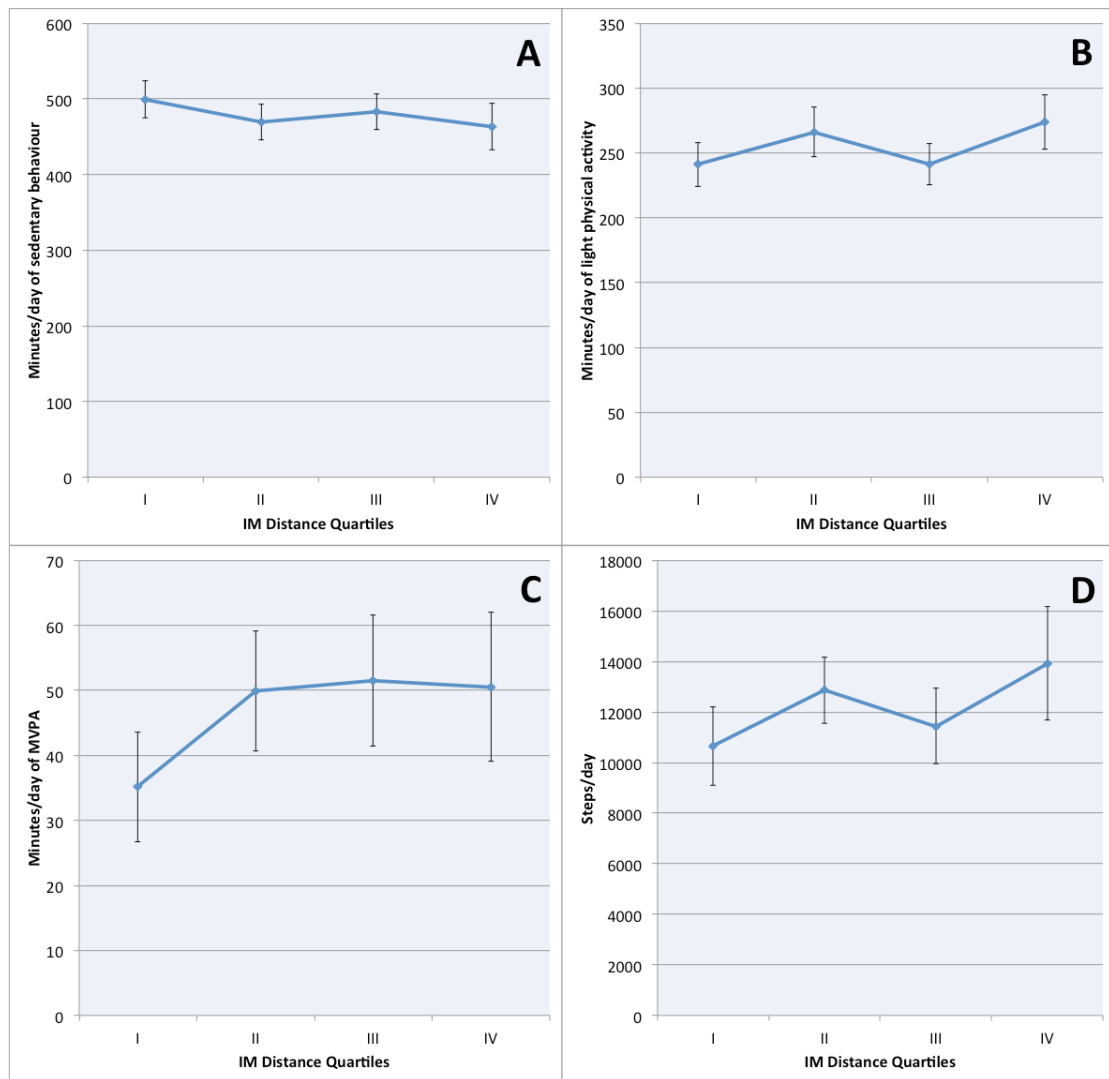


Figure 6-2. Associations between IM Distance and (A) sedentary time, (B) light physical activity, (C) MVPA, and (D) daily step count.

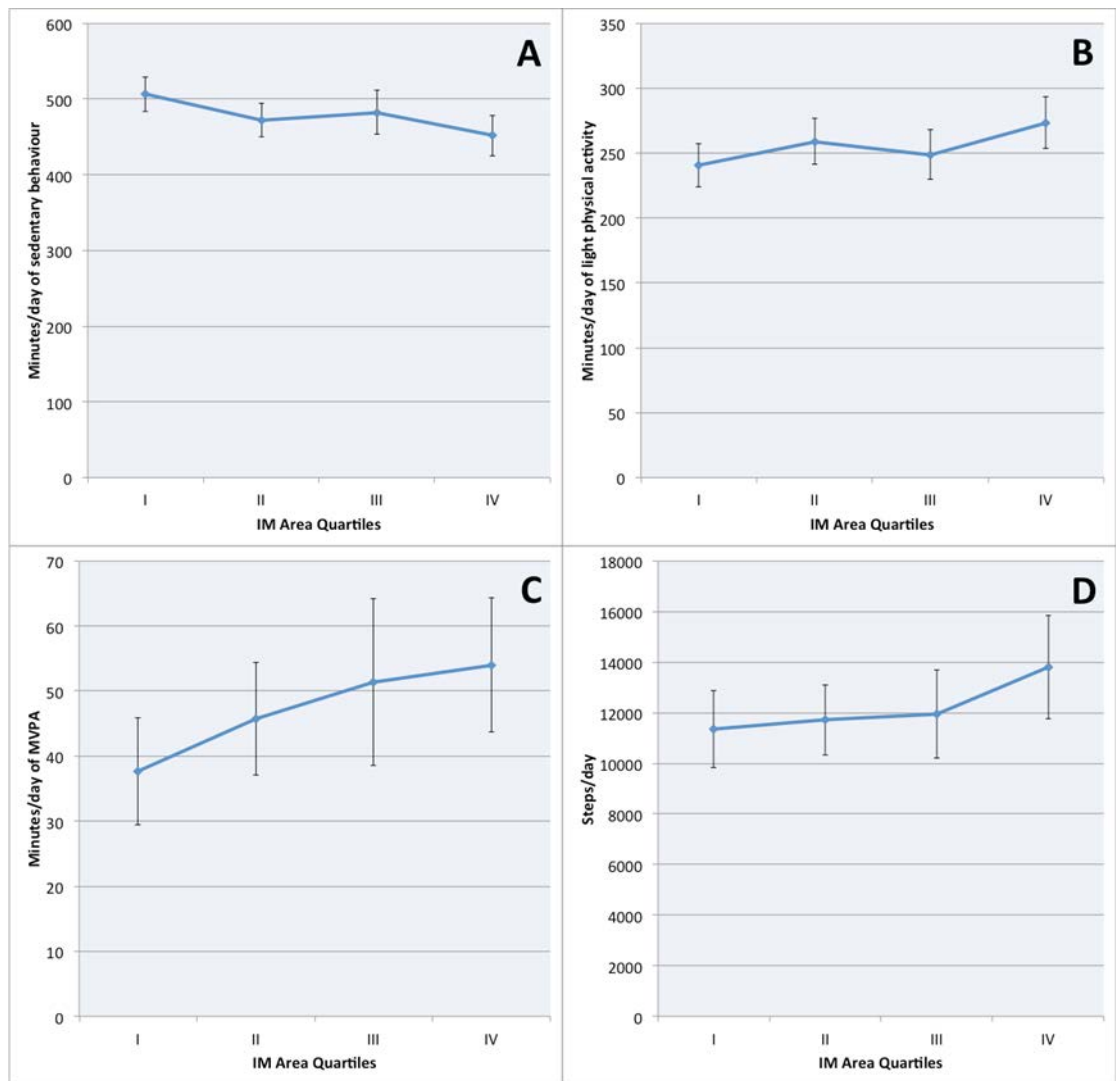


Figure 6-3. Associations between IM Area and (A) sedentary time, (B) light physical activity, (C) MVPA, and (D) daily step count.

Discussion

This study investigated associations between children's IM and light physical activity, MVPA, step counts and sedentary activity. It was expected that low levels of IM and physical activity would be correlated, and the findings clearly demonstrate this. Significant differences were observed between IMB Distance and light, moderate and total MVPA. There was also a clear (non-significant) upward trend in activity intensity and step counts across all IM quartiles. These findings are in line with previous evidence showing positive associations between IM and children's physical activity.^[15,43-45,55] In general, children in this study had low IM and low levels of physical activity. The median IMB Distance was less than 2 km from participants' home residence for both boys (1.88 km) and girls (1.10 km). Similar low levels of children's current IM distances were observed in Chapter 3 and reported in another New Zealand study.^[258] Given that 2 km has been identified as a "sweet spot" for active transport home from school, this may have some implications in children's low IM today.^[296] In regard to physical activity, daily MVPA was well below the recommended guideline of 60 minutes per day;^[3] step counts were also well under current recommendations.^[143] Previous self-reported data in New Zealand have indicated much higher levels of children's physical activity;^[57] however, other cross-sectional research shows similar low activity levels.^[144] It was interesting to see that children had very little vigorous intensity activity overall, lending further evidence to support the extent of children's declining daily activity. Overall, these datum emphasise the important contribution that children's independent free play and exploration of their local area can have on their habitual physical activity.

Significant differences were also demonstrated between children's IM and sedentary time. Children with high levels of IM spent over an hour less time sedentary than those with restricted freedoms. It is possible that in reducing children's spatial boundaries, parents are limiting their outdoor play space, driving them indoors to more sedentary-based activities, which is compounded by attractive electronic alternatives. It appeared that some children had very high levels of sedentary time; median time sedentary equated to 7.81 hours a day. While universal guidelines on sedentary time do not currently exist, it has been recommended that youth spend no more than two hours in total screen time per day (television, computer, electronic gaming) outside of school time.^[57] Provided children are at school for a maximum of six hours, it is possible that some children will be well above these recommended guidelines. Independent of physical

activity, there is a unique *inactive physiology* associated with sedentary behaviour^[305] which has a number of detrimental immediate^[95,172] and long term implications^[176] on children's health. Emerging research is suggesting a health promotion focus to an all-movement-counts approach^[130] and shifting time spent sedentary with more light-to-moderate activity.^[167] The findings from this study indicate independent activities including active transport and outdoor play could help to significantly reduce children's inactivity and lend support to this shift.

It was interesting to note that children's sex had little effect on these associations. It has previously been well highlighted in the literature that boys experience greater autonomous roaming than girls.^[23,30,205] This was evident in this study; boys had almost double the IM distance and area compared to girls. It is highly likely that there were no interactions with sex and associations of IM, physical activity or sedentary behaviour due to the insignificant differences in physical activity levels between both sexes. It is also possible that children's low overall physical activity levels and total IM have dropped to such a level that sex differences are unable to be differentiated in associations with physical activity or sedentary behaviour.

The significant differences in children's active behaviours observed in this study could be explained by a number of psycho-social and environmental factors which have influenced the decline in children's IM. Increasing urban sprawl and reduced green areas have decreased opportunities for play spaces close to home.^[306] Subsequent travel times have also increased vehicle-based trips, exacerbated by the increase in organised activities which are often considerable distances away.^[34] The perceptions of unsafe and unfriendly neighbourhoods have fuelled parents' fears and resulted in protective chauffeuring behaviours which are compounded by dual parent working dynamics.^[224] The continual development of technology which has resulted in a surge of electronic media is highly likely only going to increase exponentially, making it harder for parents to deter children from these activities.^[42] This study further highlights the worrying trending decline in IM, impacting children's health and development. Public health strategies to mediate some of these concerns may help to slow or prevent the continual decline.

Strengths/Limitations and Future Recommendations

This study provides a significant contribution to the body of children's IM literature. To date only a small number of studies have explored the relationship between children's autonomous roaming

and daily activity. Comprehensive understanding of IM has been limited by a lack of standardised measures. The geographically defined measures of IM used in this study are novel and provide robust evidence of children's current IM, which builds on the emerging research exploring associations between IM and physical activity. While differences between IMB Area and children's physical activity were not significant, they were close to being statistically significant. It is possible this was in part due to the substantial variation in perceived roaming areas (1.26; 0.303, 4.53).

Previous research investigating associations between IM and children's physical inactivity has been very limited and the findings are conflicting. This study, therefore, provide a valuable contribution to the literature on children's IM and physical inactivity. Irrespective of other associations, the low levels of physical activity and the high levels of sedentary time observed in this study are concerning and further highlight the importance of investigating behaviours which can promote or inhibit activity levels. Future investigations using a quantifiable measure of where children actually roam to in real time (e.g., global positioning systems) may further our understanding in this area.

Conclusion

This study has provided novel, robust evidence to show that children who experience severe restriction on their independent roaming accumulate significantly less MVPA and spend more time being sedentary than those granted greater IM. The creation of environments which encourage children's independent spatial mobility is crucial to help develop children's habitually active lifestyles.

Chapter 7. Associations between Children's Independent Mobility and Body Composition

Preface

Low levels of physical activity and high periods of sedentary time in children were observed in Chapter 6. Children who were granted greater freedom to play and roam in their neighbourhood unsupervised (highest quartile of IMB Distance) experienced significantly more MVPA daily (15.4 minutes). Conversely, those with restricted freedoms (lowest quartile of IMB Area and Distance) had significantly higher periods of time sedentary than those with high IM (54.5 minutes and 36.1 minutes, respectively). Physical inactivity is considered a high risk factor for childhood obesity, of which there is a global epidemic. Chapter 2 found a paucity of research examining the association between children's IM and weight status. This study will provide the first evidence of these associations, contributing significantly to the field of IM and wider epidemiological research.

Abstract

Background: Childhood obesity has reached epidemic proportions and the specific causes involve a complex interaction of genetic, behavioural and environmental factors. While emerging research suggests an inverse relationship between children's independent mobility (IM) and physical activity levels, how children's autonomous roaming relates to childhood obesity remains largely unknown. The aim of this study was to explore the association between children's IM and body composition.

Methods: Data were collected for 198 children aged 10-13 years. IM roaming areas and distance were derived from VERITAS-IM, an online mapping application, and compared to participants' body mass index (BMI), body fat percentage and waist to height ratio (WHtR).

Results: Median perceived maximum roaming boundary was 1.20 km² (IQR: 0.24, 4.67) and maximum median roaming distance was 1.63 km (0.737, 2.76). Mean BMI was 17.8(kg.m-2), with 23.4% children either overweight or obese. Binary logistical regression showed no associations between IMB Distance or Area and any body composition indicator. There were substantial confidence intervals between the lowest and highest IMB Distance quartiles for categories of overweight (OR 1.95 95% CI: 0.59, 6.34), obese (OR 0.97 95% CI: 0.13, 7.25), WHtR (OR 0.28 95% CI: 0.07, 1.10) and %BF (OR 0.97 95% CI: 0.23, 4.16). Similarly, there were no significant associations between IMB Area and either measure of body composition, with considerable variation in confidence intervals between the lowest and highest IMB Area quartiles for categories of overweight (OR 2.30 95% CI: 0.77, 6.85), obese (OR 0.71 95% CI: 0.11, 4.45), WHtR (OR 0.55 95% CI: 0.17, 1.80) and %BF (OR 0.86 95% CI: 0.22,3.40).

Conclusion: In this study there were no associations between children's IM and key measures of body composition. It is likely that a number of biological, behavioural and environmental factors also contribute to weight status in children. Potentially, the findings in this study suggest reverse causation; obesity causes low levels of activity in children. However, more research is required to understand the relationship with IM in this regard.

Introduction

Childhood obesity is an important health issue.^[100,307] Current global evidence estimates 170 million children (aged less than 18 years) are now overweight.^[50] New Zealand is no exception; presently, one in three children are overweight or obese.^[57] Both the physical and psychological consequences of children carrying excess weight are extensive. Overweight or obese children are more likely to have poor physical wellbeing^[308] or suffer low self-esteem^[309], are at higher risk of depression^[310] and experience a debilitating social stigma^[311] than normal weight children. Obese youth are also highly likely to become obese adults^[312-315], increasing the risk of numerous non-communicable diseases including cardiovascular disease, type 2 diabetes and cancer.^[5] Key biomarkers for these chronic diseases are now present in overweight and obese children, including hypertension,^[80-83] glucose intolerance^[80] and hyperlipidaemia,^[316] portraying a worrying picture for long term health trajectory.

Ultimately, obesity results from a positive sustained energy balance.^[85,87] As a major modifiable component of the energy balance equation, physical activity plays a crucial role in maintaining a healthy weight. Current evidence on the association between physical activity and childhood obesity is inconclusive. While some studies show a positive association between physical activity and obesity in youth,^[89-95] others have not.^[77,96-98] Investigation of how subcomponents of physical activity can influence obesity is imperative to understanding this relationship.

Children's independent mobility (IM) is recognised as their ability to play, roam and move either alone or accompanied by peers (without the presence of an adult).^[13] IM provides opportunities for children to engage in unstructured physical activity,^[15] take risks,^[22] form social bonds^[18] and develop emotional resilience.^[21] The amount of freedom given is heavily influenced by parenting styles and perceptions.^[317] It is generally perceived that IM has decreased from earlier generations and there is now evidence from numerous population-based studies to support this trend. Reductions in children's licences to travel and roam to certain locations have been observed in Australia,^[24] England^[49], Finland^[25] and New Zealand.^[280]

The long term implications of a reduction in children's autonomous movement remains largely unknown. Emerging evidence indicates that children who experience restriction on their spatial mobility engage in significantly less physical activity than those with increased freedoms.^[15,43-45]

Chapter 6 showed that children aged 10-13 years old who had high perceived independent roaming distances and area accumulated 15.4 minutes and 16.3 minutes, respectively, more MVPA than those with low perceived roaming distances and areas (Chapter 6). Similar findings have been reported in Canada,^[15] England,^[43] Portugal^[318] and Australia.^[249]

While it is possible there is a relationship between children's IM and weight status, mediated by physical activity, there is currently a paucity of knowledge understanding these associations. It is believed that the relationship between children's IM and body composition has not been explored in New Zealand and only a small number of investigations have been conducted globally.^[15,43] In England, children aged 10-12 years old who experience greater freedom to roam independently were more likely to have improved weight status, though this correlation was statistically weak.^[43] Conversely, in children of the same age in Canada there was no correlation found between IM and BMI.^[15] There have been some investigations exploring the associations between outdoor play (an element of IM) and children's weight status; however, evidence is also minimal and conflicting. Some studies have found lower levels of outdoor play among overweight children,^[268,272,319] while some have not.^[288,320]

Currently there are substantial research gaps in understanding the potential influence IM has on children's weight status and risk of obesity. Given the current pandemic of this health issue, there is a need to explore how subcomponents of activity can influence children's body composition. The objective of this study was to examine whether there is any direct association between children's IM, body fat percentage and waist to height ratio.

Methods

Participants

All children from three intermediate (school years 7-8) schools in the Auckland region were invited to participate. Schools were purposively selected to obtain participants from a range of socio-demographic and ethnic backgrounds. One school had the highest socio-economic decile rating (10), the second had a decile rating of 6, and the third school had a decile rating of 3. All children were provided with an information sheet and consent/assent forms to take home, and only those who gave written assent, and their parent or guardian provided written consent, were selected to

participate in the study. Ethical approval for the study protocol was obtained from the host institute's Ethics Committee AUTECH (Refer to Appendix B).

Procedure and Instruments

Data collection took place during school hours at a designated time during 2013. Cross-sectional data were measured in a series of stations run by trained researchers. Height was measured to the nearest millimetre with a portable stadiometer and weight to the nearest 0.1kg using calibrated digital scales (Seca 770). BMI was calculated as weight (kg) divided by squared height (M^2). Waist circumferences were measured using standardised protocols^[321] and waist to height ratio (WtHR) was then calculated. Percentage of body fat (%BF) was measured with hand-to-foot bioelectrical impedance analysis (BIA; Impedimed DF50), which has been validated for use in children.^[322]

IM was measured through the maximum independent boundary area (IMB Area) and distance (IMB Distance) participants believed they could roam unsupervised, derived from the online mapping programme VERITAS-IM. The details of VERITAS-IM have been described before (refer to Chapter 4). Briefly, VERITAS-IM was developed from the original VERITAS application (VERITAS-RECORD)^[46] and specifically customised to capture children's IM. The programme consists of a sequential series of interactive maps, embedded within Google Maps functionality and tenanted with key questions regarding children's spatial mobility. With assistance from trained research technicians, participants identified on integrated maps their home residence and locations they had been independently mobile in the last six months and seven days. Using these locations as a guide, participants drew a polygon shape around the area in their neighbourhood which they perceived is the maximum area they can be independently mobile. These datum were imported into ArcGIS 10.1 (ESRI, Redlands, CA, USA) and after being inspected for any errors, IM Boundary Area (IMB Area) was calculated as the area inside the perceived IM boundary polygon, and IM Boundary Distance (IMB Distance) was calculated as the Euclidean distance (i.e., as the crow flies) from the home residence to the furthest point in the perceived IM boundary polygon (Figure 7-1).

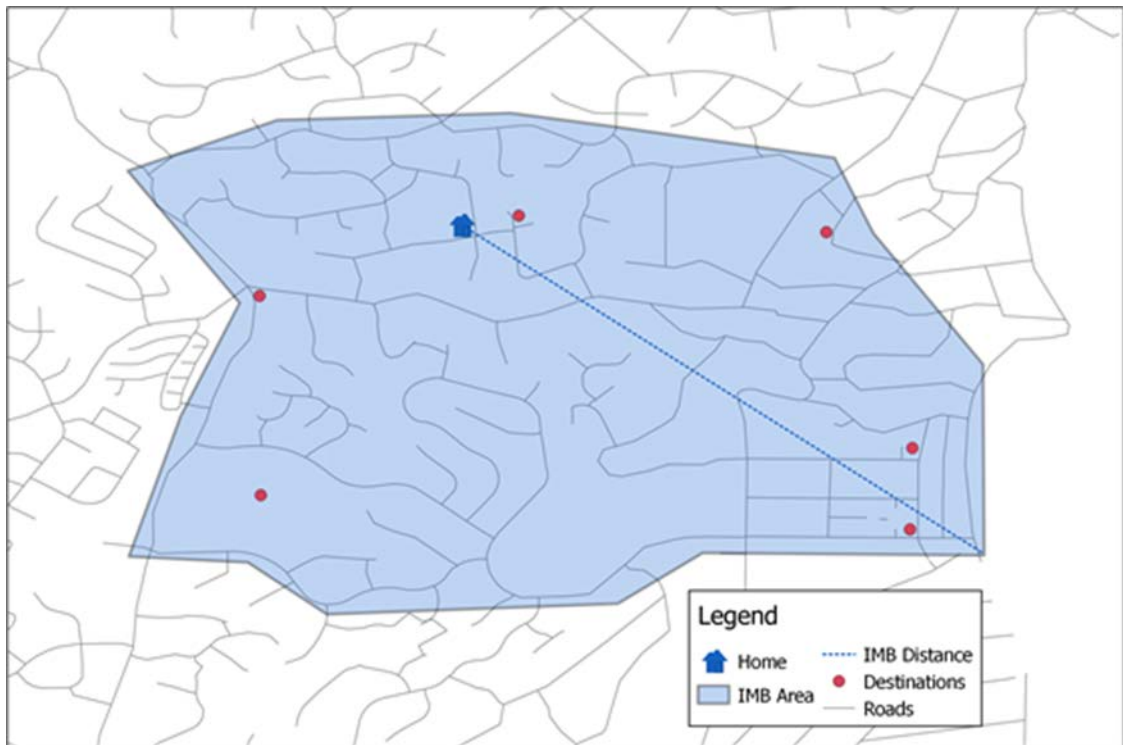


Figure 7-1. VERITAS-IM derived IM Boundary Area (IMB Area) and IM Boundary Distance (IMB Distance)

Data Analysis

To assess the relationship between IM and the body composition indicators most relevant to public health, all continuous body composition variables (BMI, WHtR, %BF) were converted into binary variables using commonly accepted high risk thresholds. First, BMI was categorised into overweight and obese using the age- and sex-specific cutpoints developed by the International Obesity Taskforce.^[323] Second, WHtR was categorised into high and low groups using 0.5 as the threshold.^[321] Third, the 90th percentile of %BF was used to categorise participants into high and low %BF groups.^[324] Binary logistic regression analysis was then implemented to determine the associations of each body composition variable with IMB Area and IMB Distance quartiles. Odds ratios for each association were adjusted for age and sex. Statistical significance was set at $p < 0.05$, and all analyses were conducted using IBM SPSS Statistics (V. 20).

Results

Descriptive data are presented in Table 7-1 for 198 children (99 male and 96 female) with a mean age of 12 years (SD = 2.19). Mean BMI was 17.8 kg.m-2, with 23.4% children either overweight or obese. Mean body fat percentage was 22.1 (\pm 9.23) and mean WHtR 0.44 (\pm 0.06). There were no significant differences between males and females for any body composition variables. Median perceived maximum roaming boundary was 1.20 km² (IQR: 0.24, 4.67) and maximum median roaming distance was 1.63 km (0.737, 2.76). There were significant sex differences in both IM measures. Boys had significantly higher IMB Area and IMB Distance than girls.

Table 7-1 Independent mobility and body composition descriptive statistics

Physical characteristics	Boys		Girls		All	
	N	Mean \pm SD	N	Mean \pm SD	N	Mean \pm SD
Age (years)	99	11.9 \pm 2.19	96	11.8 \pm 2.22	198	11.7 \pm 2.62
Height (m)	99	1.55 \pm 0.085	96	1.55 \pm 0.082	198	1.55 \pm 0.082
Weight (kg)	99	48.3 \pm 13.3	95	48.8 \pm 10.5	197	48.6 \pm 11.9
Body mass index (kg.m-2)	99	17.8 \pm 4.81	95	17.9 \pm 4.36	197	17.8 \pm 4.57
Waist circumference (cm)	99	68.9 \pm 9.20	95	67.4 \pm 10.8	197	68.2 \pm 10.0
Waist-to-height ratio	99	0.444 \pm 0.052	95	0.435 \pm 0.069	197	0.440 \pm 0.061
Body fat Percentage (%)	99	21.4 \pm 8.66	95	22.7 \pm 9.73	197	22.1 \pm 9.23
IM	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)
IM Distance (km)	94	1.92 (0.991, 3.23)	88	1.26 (0.574, 2.30)*	182	1.63 (0.737, 2.76)
IM Area (km ²)	94	2.11 (0.388, 5.78)	88	0.641 (0.162, 2.94)*	182	1.20 (0.24, 4.67)

*Significantly different from boys ($p < 0.05$).

Figure 7-2 shows there were no associations between IMB Distance and body composition indicators, with substantial confidence intervals between the lowest and highest IMB Distance quartiles for categories of overweight (OR 1.95 95% CI: 0.59, 6.34), and obese (OR 0.97 95% CI: 0.13, 7.25), as well as for WHtR (OR 0.28 95% CI: 0.07, 1.10) and %BF (OR 0.97 95% CI: 0.23,4.16). Likewise, Figure 7-3 demonstrates considerable confidence intervals between the lowest and highest IMB Area quartiles for categories of overweight (OR 2.30 95% CI: 0.77, 6.85), and obese (OR 0.71 95% CI: 0.11, 4.45), as well as for WHtR (OR 0.55 95% CI: 0.17, 1.80) and %BF (OR 0.86 95% CI: 0.22,3.40). Subsequently, no significant associations were found between IMB Area and either measure of body composition.

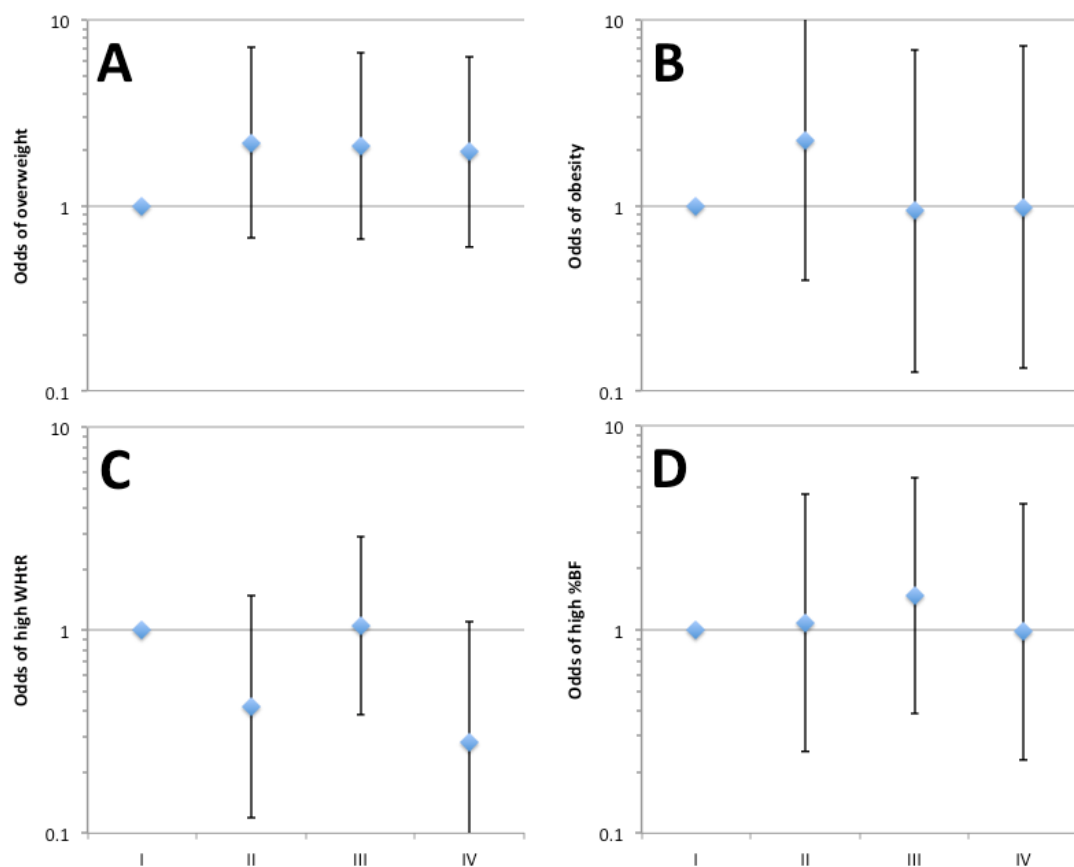


Figure 7-2. Associations between IMB Distance and (A) overweight, (B) obesity, (C) high WHtR, and (D) high %BF.

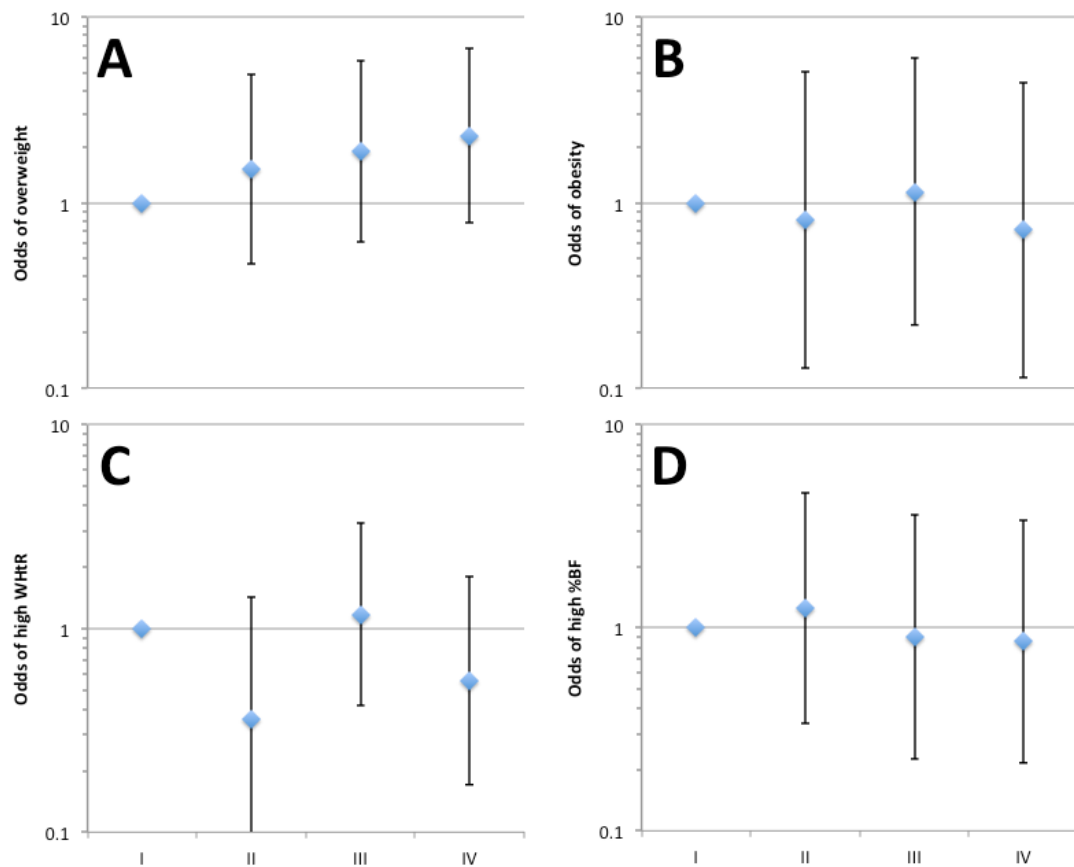


Figure 7-3. Associations between IMB Area and (A) overweight, (B) obesity, (C) high WHtR, and (D) high %BF.

Discussion

This study investigated associations between children's geographically defined IM and body composition. In this study, mean BMI was 17.8 (kg.m-2), with 23.4% of participants either overweight (18.3%) or obese (5.10%). These findings are similar to overall population rates of childhood overweight and obesity in New Zealand (22.5% and 13.0%, respectively)^[57]. It was also apparent in this study that children had low overall levels of IM; the medium maximum roaming distance was less than 2 km from participants' home residence for both boys (1.92 km) and girls (1.26 km). Similar low levels of children's current IM distances were observed in a previous New Zealand study.^[258] However, in this sample, children's independent roaming distances and areas were not related to BMI, WHtR or %BF. It is believed that this is the first study to explore the association between children's IM and a broad range of quantifiable measures for body composition. There are a number of possible reasons for not observing any direct associations.

There are several methodological considerations with this study which need to be accounted for. The ability of children to play and roam in the neighbourhood does not summarise total daily activity. Consequently, a mediated relationship between children's IM and measures of body composition would have been expected at best. Given the low overall levels of IM observed in this study (median roaming distance was less than 2 km from home), it is also possible that there was not sufficient difference in the magnitude of IM to detect variation in body composition. Moreover, IM is a socio-environmental measure of where children are allowed to play and roam, rather than where they are actually independently mobile. If there is substantial discourse between IM allowances and actual unsupervised roaming, it is unlikely that children's IM would mediate differences in body composition alone.

The longstanding paradigm to weight maintenance has focused on balancing energy intake with energy expenditure. While this hypothesis is a truism, it implies that the balance of energy is an open loop system and does not reflect the complex biochemical pathways involved in metabolism at a cellular level. Understanding that the causes of obesity go beyond simply matching calories in with calories out is becoming increasingly apparent in the literature.^[108,113,325,326] Attention is now particularly being given to the hormonal, inflammatory and metabolic characteristics of obesity, including hyperinsulinaemia and leptin resistance.^[316,326,327] There is evidence that chronic hyperinsulinaemia can interfere with leptin's signalling; reducing satiety, driving energy intake and decreasing physical activity.^[326,328,329] It has also been shown that immune cells infiltrate adipose tissue at the onset of weight gain, accelerating the inflammatory state of fat and systemic insulin resistance.^[330,331] Moreover, there is also evidence that these biochemical pathways are affected by other biological factors including stress and sleep which further promote insulin resistance.^[106,107,332] It is highly probable that there are a multitude of genetic, biological and environmental factors other than IM which influence children's body composition.

It has also recently been suggested that low physical activity in children results from increased adiposity; i.e., causation is bi-directional.^[112,113,115,325] Ludwig and colleagues (2014) have proposed an alternative model in which dietary composition (especially the consumption of highly refined carbohydrate and high-fructose corn syrup) and genetic/lifestyle factors (including stress and sleep) increase fat storage, decreasing circulating metabolic fuels, and subsequently increasing hunger while simultaneously reducing energy expenditure.^[333] There is emerging

research to support this reverse causality. For example, The Avon Longitudinal Study found an increase in BMI associated with less MVPA and more sedentary time in children aged 11 years old.^[113] Similarly, in another longitudinal study of 8-11-year-olds, increased fat mass at baseline was associated with decreased MVPA and increased sedentary time after 200 days.^[112] It is possible that the observed decreases in children's independent roaming and associated low levels of activity have resulted from the increased prevalence of childhood obesity. Potentially, this reverse causation explains the findings in this study in alignment with low activity levels reported in Chapter 6. Ongoing investigations would be recommended to understand this potential bi-directional relationship.

Conclusion

Childhood presents a crucial juncture in the development of physically active behaviours which may mediate the global epidemic of overweight and obesity. Results from this study indicate that children's independent mobility alone may not influence the complex biochemical pathways of childhood obesity. Potentially, there is a bi-directional causation between children's physical activity and obesity; however, further empirical evidence is required to understand this relationship. Pinpointing and isolating singular influencing factors in the development of childhood obesity is going to be an ongoing challenge for health research.

Chapter 8. Discussion

Summary

Physical inactivity is a prevailing global health concern associated with numerous debilitating chronic diseases.^[3] Global evidence indicates that a significant number of children in both developed and developing countries have low levels of daily physical activity, spending the majority of their day inactive.^[7] Concurrent is the presence of biomarkers for chronic illness now visible in children, including obesity, hypertension and metabolic syndrome; predictive of a concerning future for young people today.^[80,334]

The modern environment is now one where it takes considerable effort to move daily. Instilling patterns of activity in children which can track into adulthood is an obvious public health target. While global guidelines have been developed and adopted by many health policy makers, in light of current global evidence on children's activity patterns, their implementation on a "ground floor" level has been largely ineffective. Potentially, a lack of clear evidence lies at the source of the issue, as the full extent of the problem is unclear on a national level. In New Zealand the most recent population-based data, self-reported and published five years ago, indicates that the majority of children conform to recommended guidelines of 60 minutes MVPA a day. However, these findings are not supported by recent evidence using objectively measured physical activity.^[143,144] Findings from this series of studies indicated that median MVPA daily was 39.8 minutes, with girls doing significantly less than boys (35.5 minutes vs. 42.8 minutes, respectively). These datum dovetail with emerging research to demonstrate a growing public health concern in children's inactivity.

Investigation into behaviours which can inhibit or promote physical activity in children is without question a priority. While IM presents opportunities for children to naturally accumulate physical activity, a lack of standardised methodology has limited current knowledge of the decline in this fundamental behaviour, and possible associations with physical activity, sedentary time and obesity have been largely unknown. Founding evidence captured with robust methodology is an essential starting point to develop evidence-based strategies to promote physical activity for children.

Central aims of the thesis were to address this research gap by developing and testing robust measures of IM, and applying these methods to explore associations with key physical health outcomes.

Research Summary and Implications

This body of work makes a novel contribution to children's IM literature and the field of physical activity in New Zealand and internationally in several ways.

Measurement of Independent Mobility

A detailed critique of the literature (Chapter 2) revealed that a priority issue was the absence of standardised methodologies to accurately determine children's IM. This body of work provides an important contribution to the field of children's IM through the development of several reliable IM measures.

IM Licence

Children's independent licences to go to certain places unsupervised have been a popular measure to date.^[23,30,48,49] However, there has been little academic consensus on the conceptual definition of an IM Licence. Findings from Chapter 3 highlighted this inconsistency and called for clarification around the term. The IM Licence in Chapter 4 included six key allowances, previously used in a number of international studies,^[23,30,48] and specifically defined the level of supervision as being "allowed to do the following either by yourself or with friends (without an adult)". Participants were given the option to respond with either yes, no, or not sure. The option of "not sure" was a novel addition to allow for variation in responses other than a "yes" or a "no". Given the previous popularity of IM Licences, it is envisioned that the precise definition of this measure, refined in this thesis, is replicated in future studies.

IM Index

In order to capture the degree to which children are allowed to roam to certain locations with a quantifiable outcome, an IM Index was created. The IM Index was explored for use across three generations in Chapter 3 and it was found to be feasible and practical, especially for large population-based studies; subsequently, this measure was used in Chapters 4 and 5. The

questionnaire from which this measure is developed has been used in a previous investigation^[43]; however, the formation of an index from the responses is original and provides a potentially standardised measurement option.

VERITAS-IM

Neither of the questionnaire-based estimates of IM provided geospatial data. Review of the literature identified the growing popularity of a mixed methods approach as a new research paradigm.^[335] Concomitantly, modern technological developments have given rise to online mapping applications which were identified as a potential way to capture IM data via a mixed methods approach (Chapter 2). Prior to this thesis, online mapping applications had not been used in New Zealand, and only a small amount of research had explored this methodology internationally.^[46,47]

In Chapter 3, the use of online mapping was explored with 45 participants of directly related children, parent and grandparent triads. A singular IM determinant (IM Maximum) was found to be correlated with IM Index, offering a novel quantifiable measure. However, measurement did not account for independent roaming boundaries or potentially influencing variables, such as travel mode and companionship. The development of VERITAS-IM (Chapter 4) customised for use with children encapsulated this data, providing an important and novel contribution to research. The data collection procedure with this innovative application was found to be interactive, engaging children as key agents in the research process, which may be an important consideration for future investigations.

Measurement Comparability

The development of VERITAS-IM was innovative and novel; subsequently, it was important to assess how the measures of IM derived from the application compared with more traditional IM indicators. It is believed that this is the first study to investigate how different IM measures relate to each other, providing an important contribution to knowledge. Findings from Chapter 3 suggested that IM Index and IM Maximum were to a certain degree related. A significant linear trend was observed between IM Index and IM Maximum for children only (IM Maximum = $1.60 \times \text{IM Index} + 0.289$, $R^2 = 0.334$, $p = 0.006$) and across all generations (IM Maximum = $2.92 \times \text{IM Index} - 1.23$, $R^2 = 0.205$, $p = 0.002$).

Data from Chapter 4 demonstrated both IM Index and IM Licence were significantly related to VERITAS-IM-derived measures. In regard to IM Index and VERITAS-M, for every one unit increase in IM Index, IMB Area increased by nearly 4 km², and IMB Distance increased by 1 km. Similarly, for participants who had parental licences to travel unsupervised to all contexts, except to go out after dark (to and from school, cross and cycle main roads, and use public transport) IMB Area ranged from 1.46 to 2.45 km² compared with 0.12 to 0.43 km² in participants who were not permitted these licences. Likewise, median IMB Distance ranged from 1.68 to 2.15 km in participants who were permitted to travel unsupervised in the selected contexts (except to go out after dark) and from 0.57 to 1.36 km in participants who were not. In addition, this study showed destination-based estimates of IM area and distance were significantly lower than boundary-based estimates. On average, IMD Area underestimated IMB Area by 100% (7-day method) and 88% (6-month method). Similarly, IMD Distance underestimated IMB Distance by 67% (7-day method). However, IMD Distance and IMB Distance were more equivalent when IMD was determined over six months; the percent difference was significantly different from zero in males only. These datum emphasise the importance of employing a measurement technique that quantifies maximum independent roaming distances, locations and boundaries as children can roam unsupervised without a specified end destination. Potentially, children may only roam to their maximum IM boundary occasionally; i.e., once or twice in six months, which is an important consideration for future research. Overall, these findings highlight the potential benefits of a mixed method approach amalgamated with online mapping in capturing the complex nature of children's IM, potentially providing a standardised measurement technique which has been absent.

Intergenerational Change

Prior to this thesis, assessment of intergenerational change in children's ability to play and roam unsupervised had not previously been conducted. This is the first work to assess differences in children's IM and active transport to and from school using directly related participants. In Chapter 3, exploration of three generations of directly related participants indicated a drastic decline in the mean maximum roaming distance from children's home residence across grandparents (7810m, 7064), parents (5335m, 4940) and children (2673m, 1929). Similar declines were observed in IM Index (2.54, 0.28; 2.28, 0.44; and 1.49, 0.7; respectively), and only one child experienced the same completely unrestricted licence as their parents and grandparent experienced; i.e., being allowed to go anywhere in the neighbourhood without adult supervision.

In Chapter 4, data from IMB Area indicated 26% of all participants had not gone anywhere in the previous seven days without an adult and 7.8% had not been anywhere unsupervised in the previous six months. This evidence was further supported in Chapter 5, which showed a significant decrease in IM Index between 500 parents and children. Significant reductions in IM Licences regarding traveling to school, crossing main roads, cycling main roads and going out after dark were also observed. The most apparent were the reductions in the number of children allowed to cycle main roads, (a decline from 76.0%-43.2%); and the percentage of children using active modes of transport to (91.8%-49.3%) and from (93.2%- 56.9%) school.

Overall the significant intergenerational decreases observed in this thesis align with current international research. Research conducted in England^[23], Australia^[24], Norway^[290] and Italy^[206] have reported similar significant declines in the parental permission for children being allowed to go and travel to certain locations on their own. However, while greater restrictions in parental licences in this thesis were observed between generations, the majority of the child participants were still granted a number of licences including being allowed to travel to and from school, cross main roads, and travel on buses/trains (62%-91.6%). These findings are similar to a previous New Zealand study conducted in Christchurch^[30] as well investigations in Germany^[23] and Finland.^[25] Conversely, research conducted in England, Australia, Norway and Italy have indicated a significantly smaller percentage of children to be granted parental licences to be independently mobile. Such disparities between countries were found in a recent large international study comparing the parental licenses of 16 countries.^[291] It is possible considerable differences in features of the built environment and geographical landscapes between countries could significantly affect the amount of freedom children are granted to explore their local area. Evidence exploring these associations further could provide increased understanding of the international differences in children's IM.

Wider Implications

Outcomes from Chapter 5 draw attention to how changes in modern parenting have potentially fuelled the decline in children's IM. Organised activities more than doubled from a mean of 1.75 activities per week (parents) to 4.06 (children). It is likely that an increased social focus on sporting and academic achievements in children^[214] has underpinned this upsurge in formalised activities.

It is conceivable that the high number of structured pursuits which children are enrolled in have displaced their opportunities for free play and roaming in the neighbourhood.

It was also observed in Chapter 3 that parents now have a number of concerns for their children exploring the local area on their own, specifically from high traffic volumes and “strangers”; concerns which their own parents did not have when they were the same age. These perceptions may have also supported the preference for children to be in organised activities after school and on weekends to help keep them safe from such potential dangers.^[34] In addition, these parenting norms may have also led to children being increasingly driven to and from school, influencing the decline in children's use of active travel modes. It is worth noting that this is despite children experiencing increased bicycle ownership compared to their parents' childhood.

There have also been changes to the nuclear structure of a modern family, which may have contributed to the challenges parents encounter in allowing children IM. In New Zealand, the conventional make-up of a modern family (as reported in 2012) is one couple with 2.1 children; a decrease from an average of 4.3 births per woman in 1961.^[211] These changes are also reflected internationally, with the mean child per family in the Organisation for Economic Cooperation and Development (OECD) dropping from 2.7 in 1970 to 1.74 in 2009.^[212] In parallel, the mean age at which New Zealand women start a family is now 30 years old, compared with 26 years old in 1960.^[211] Consequently, there has been an overall decrease in the proportion of large families, and children are growing up with a reduced number of siblings. It is possible that as a result children's ability to play and roam unsupervised in the neighbourhood has been affected, as previous literature has reported children with older siblings are more likely to be granted higher levels of IM.^[202]

A plausible driver to the changes in modern family structures is the conflict an increasing number of women face in attaining both their career and family aspirations.^[336] Between 1991 and 2012, the proportion of women holding a post-school qualification increased from 32%-50%, and subsequently there has been an increase in women in the labour force from 49%-58% over the same time period.^[211] It is possible women are postponing child bearing in order to establish themselves in the workforce. Moreover, the number of dual-working parents is subsequently increasing,^[213,337] which can create a complex and time consuming transport schedule; i.e., to and

from work and school, potentially reducing opportunities for autonomous roaming and active transport home from school.^[34]

Concurrently, there has also been dialogue in the literature of conflicting societal attitudes emerging regarding the concept of a “good mother”.^[214,338] It has been suggested that mothers feel they should hold a career and contribute to society through paid employment and at the same time they should also be at home with their children, especially young infants.^[336,338] It is possible that out of this social pressure, mothers in the paid work force feel the need to spend more time with their children, reducing their opportunities for unsupervised play. It is also possible that one of the motives for women to work is being able to “provide the best” for their children; for example, being able to afford paid structured activities.

This pressure is further compounded by the cost of living. The cost of housing in New Zealand (average house price in New Zealand \$527,760 at June, 2015)^[339] has surpassed wage growth (median estimated yearly income, \$32,292 per annum).^[340] Consequently, housing on a single income is unaffordable for a significant number of families. It was recently reported that 29% of dual-earner couples with dependent children worked 80 or more combined hours and 8% worked more than 100 combined hours. The impact of long work hours on a family is substantial, including sleep deprivation, stress, and low overall wellbeing.^[336,341]

Despite long working hours, emerging evidence suggests that parents are now spending three times more time with their children from one generation earlier.^[342,343] Such parenting practices are distinctly different to previous generations. Qualitative findings from Chapter 3 note that grandparents recall their children mainly playing in the street with other children. Similarly, oral history literature has reported earlier generations recalling the home was not one in which play took place.^[26,238] Conversely, there is evidence showing that children yearn for more freedom and feel that they are capable of negotiating some of the dangers in the neighbourhood, as observed in Chapter 3.^[36,280] The conflict being parents are more time pressed than previously reported and feel the social pressure to spend more time with their children; yet children want and desire more opportunities to play unsupervised.

Associations between Independent Mobility and Physical Health Indicators

Independent Mobility, Physical Activity and Sedentary Behaviour

Results from Chapter 6 showed that children's IM roaming distances and area were associated with physical activity and sedentary time. Participants with high IMB Area and Distance accumulated 16.6 minutes and 15.4 minutes more daily MVPA, respectively. In contrast, children with decreased IM spent more time being sedentary than children with increased freedom. Participants with low IMB Area and Distance spent 54.5 minutes and 36.1 minutes, respectively, more time sedentary than those with high IM. Previously, only a limited number of studies had explored the relationship between children's IM and daily activity; sedentary time even less so. Certainly previous research had not been undertaken with the robust IM methodology as was employed in this thesis. This is the first line of investigation to employ interactive mapping in order to understand the possible relationship between IM and physical activity. This evidence builds on emerging international research and provides the first data of these associations in New Zealand children, significantly contributing to the body of children's IM literature.

Epidemiological Shift

From a wider epidemiological standpoint there appears to be a need for a shift in health promotion focus from achieving minimum MVPA guidelines to an all-movement-counts approach in children. The long-standing focus on structured, planned exercise has subsequently fostered the social-foci of this in youth. However, children naturally move spontaneously in intermittent nature,^[344] and an emphasis on set time bouts and intensity does not reflect this. There is emerging research to support the shift from MVPA, especially in regard to breaking up sedentary time.^[305] The World Health Organisation also emphasises the importance of regular movement for children, irrespective of the risk.^[3] Evident from data in Chapter 6, it is conceivable that children's IM could provide a valuable contribution to children's habitual activity on a daily basis. However, the challenge for health promotion initiatives is in developing effective structures to support unsupervised movement in children's everyday life.

It is apparent that parents play a pivotal role in children's IM. A number of changes in the immediate structure of a modern family are interdependent with parents' perceptions of the safety of the local area, which can heavily influence children's unsupervised freedoms. It is also clear

that there is a discourse between parents' assessment of their children's ability to roam and play without adult supervision and children's personal perceptions. The emergence of parenting styles in which children are "mollycoddled" and "bubble-wrapped"^[196,345] may need to be mediated to encourage parenting practices which support children's IM. Currently, little research exists on how parenting styles can influence children's unsupervised roaming. However, there is some evidence to suggest that certain parenting approaches can influence children's physical activity.^[346] Further investigation in this area may provide a potential platform to develop interventions encouraging new social norms and behaviour which are more conducive to children's IM.

Independent Mobility and Body Composition

Prior to this body of work, only a small number of studies had previously explored the relationship between children's IM and BMI, with conflicting results^[15,43]. This was the first study to investigate the association between geographically defined children's IM and a number of reliable body composition determinants. The findings in Chapter 7 showed nearly a quarter of the participants were classified as either overweight or obese; however, there were no associations between children's independent roaming and body composition. These findings were underpinned by sizeable confidence intervals for the odds of the different body measures being associated with each IMB Area and IMB Distance quartiles, even after adjusting for age and sex. Amalgamating the outcomes from Chapter 6 (which demonstrated clear associations between children's IM, physical activity and sedentary time in the same sample), it is possible that independent mobility does not mediate the complex causal pathway of obesity in isolation.

Implications for Health Promotion

The immediate and long term impacts of obesity in youth are severe.^[126,347] This body of work highlights how the causation of obesity is more complicated than traditionally understood. The long-standing paradigm of weight maintenance heavily focuses on behavioural factors contributing to obesity.^[333] Children do not make a conscious choice to become obese; neither do they deliberately eat nutrient-poor foods or spend significant portions of their day inactive. This is a biological contradiction for how they are designed to live. The emphasis that obesity is self-inflicted and is the personal responsibility of each individual cannot apply to the paediatric population. However, this has been the primary attention of numerous interventions, many of which

have met with limited success, especially long term.^[50,347] Emerging research has indicated that there may be a bi-directional relationship between obesity and physical activity.^[112,113,115,333] In addition, increasing attention is being given to the hormonal, inflammatory and metabolic characteristics of obesity and how dietary composition can influence these.^[325,326] Potentially, a greater understanding of the biochemical pathways contributing to this debilitating disease in youth may expose a more viable foundation on which to build effective health promotion strategies.

Study Limitations

The series of studies conducted had the following limitations:

1. Chapter 3 consisted of an exploratory pilot study; subsequently, the sample size was small. Caution needs to be taken when making generalisations from the findings.
2. In conducting the pilot study for Chapter 3 it was found that grandparent participants were difficult to recruit due to unavailability. This resulted in a proportionately lower sample size. In addition, it was found for some grandparent participants that the location of their home residence had changed from a rural area to an urban area, and in some instances were difficult to locate exactly on Google Maps. It is possible this limited the recall ability for this generation. Given these limitations, it was decided that only parents and children would be recruited for the intergenerational study in Chapter 5.
3. In Chapters 4-7 there was a low response rate at two of the schools, especially in the lowest socio-economic area (8%). As a result, the sample was predominately European and not necessarily representative of the general population.
4. Accelerometers are now widely acknowledged as providing a practical, reliable and valid means of quantifying the amount and intensity of physical activity and sedentary time in children.^[41] However, they are still open to limitations. Given the rise of structured organised activities children partake in, not being able to wear the accelerometer during water sports may have influenced overall activity levels in Chapter 5. Although participants would have most likely made a note of this in their activity log, currently manual entering of accelerometer data is not yet standardised and therefore not used in

this study. Specifically regarding sedentary time, it was not possible to differentiate between the types of sedentary behaviour; i.e., television watching, reading or video games. Potentially the cut point for sedentary time is likely to also include standing (activities of limited movement). In addition, accelerometers cannot measure load carriage and any upper body movement cannot be assessed.

5. In regard to the VERITAS-IM application developed for Chapters 4-7, this was a customised programme; however, there were some technical limitations. One of these was that in the original design of the programme each question required a marker to be placed on the map. This may have implied that something was required to be marked at each question. In the instance that a participant did not need a marker placed on the map (for example there were no locations they were allowed to go to unsupervised), a marker was placed on the home location. In addition, while the measures of IM in this series of studies were novel and innovative, they are still self reported in nature. It has been identified that by the age of four, children have developed the skills for mapping accurately.^[348] However, a recent pilot study investigated the correlation between GPS and self-reported child mapping techniques for 5-12-year-olds (n=17) in measuring location and distance travelled from home.^[205] No significant difference was found between the two methods, but high individual error was noted. It is possible that children experienced some difficulty recalling their independent roaming distances and locations for Chapters 3-7.
6. Specific to the measurement of children's IM it is important to acknowledge the current discourse on how this behaviour is defined and the conceptual difference between measuring *actual* mobility and mobility *allowances*. In chapters 6 and 7 IM Boundary Area and IM Boundary Distance were used to investigate associations between children's IM, physical activity, sedentary time and body size outcomes. These measures were determined as the most ecologically robust measures to assess mobility allowances which derived from the VERITAS-IM application in Chapter 4. Further investigation into the association between children's actual mobility, activity levels and weight status may extend understanding of the potential impact children's IM has on these key health outcomes.

Future Research

This body of work provides an important platform for understanding how IM has declined and the impact this can have on children's health and wellbeing. Provided there remains an absence of a standardised measure to determine children's IM, ongoing work in this research field is required.

It is paramount that an academic consensus is made on the conceptual definition of "independent mobility" and reliable measurement techniques. The measurements refined for use in this thesis offer a number of potential standardised options. In particular, this series of studies clearly identified significant benefits in utilising an online mapping application. Further research using these IM indicators is required to determine both validity and reliability, especially in relation to more quantifiable mobility assessment procedures. For example, taking into account built environment influences by combining online mapping data with GIS and amalgamating with GPS for a more objective measurement tool.

This was the first research to determine the intergenerational change in children's IM. Further international evidence is required to solidify understanding of how children's ability to play and roam unsupervised has changed globally. In particular, knowledge of changes in IM in developing countries may offer unique insights into how features of the built environment in modern cities has impacted children's natural movement in the local area. It would also be worth investigating changes in IM with younger children; i.e., those still in primary school but of an age in which unsupervised roaming is developmentally viable. Potentially there is a "tipping point" at which parents allow their children independent freedom, and identifying factors which determine this point could help form effective interventions to apprehend the trending decline in this behaviour.

Evidence from this thesis indicates that IM has potential to impact children's physical activity levels and sedentary time. It would also be advantageous to determine specific time points at which IM occurs in relation to physical activity and at what intensity. This may provide additional insights into the benefits that incorporating habitual movement into everyday life can contribute to overall activity levels. Potentially, longitudinal evidence could help determine if a change in children's independent mobility is associated with a concomitant change in physical activity across the lifespan.

The complex nature of children's IM calls for the creation of multilevel interventions which account for the interaction of numerous environmental and psycho-social influences. Overall, it is important that the measurement tools employed in this thesis are used across a range of populations in a variety of countries and settings, including some representative samples. This is essential to understand the magnitude of the changes in IM between generations and the contributions that IM could make to children's physical health outcomes. Crucially, this evidence will provide the foundation for further investigations exploring whether children's IM can be increased through policy, social, environmental and behavioural interventions.

Conclusion

The development of an innovative online mapping application and the comparison to traditional IM indicators is a valuable contribution to the research field. Novel, geographically defined IM measures has enabled the collection of robust empirical evidence which is fundamental to understanding the complex nature of children's IM and how it has changed between generations. It is evident from this research that children's IM has declined drastically and that allowing children greater freedom for IM can significantly increase their physical activity and reduce their sedentary time. Further investigation into forming effective multilevel interventions encouraging children's independent roaming and play in the public sphere is required.

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Appendices



MEMORANDUM

Auckland University of Technology Ethics Committee (AUTECH)

To: Scott Duncan
From: Charles Grinter Ethics Coordinator
Date: 21 July 2011
Subject: Ethics Application Number 11/121 Free-range kids: Intergenerational differences in independent mobility.

Dear Scott

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 (AUTECH) at their meeting on 9 May 2011 and I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTECH's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTECH's meeting on 8 August 2011.

Your ethics application is approved for a period of three years until 20 July 2014.

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

- A brief annual progress report using form EA2, which is available online through <http://www.aut.ac.nz/research/research-ethics/ethics>. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 20 July 2014;
- A brief report on the status of the project using form EA3, which is available online through <http://www.aut.ac.nz/research/research-ethics/ethics>. This report is to be submitted either when the approval expires on 20 July 2014 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTECH is notified of any adverse events or if the research does not commence. AUTECH approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTECH 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.

When communicating with us about this application, I ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact me by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 8860.

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

Yours sincerely

Charles Grinter

On behalf of Dr Rosemary Godbold and Madeline Banda **Executive Secretary**
Auckland University of Technology Ethics Committee

Cc: Julie Martin julie.bhosale@aut.ac.nz, Grant Schofield



MEMORANDUM

Auckland University of Technology Ethics Committee (AUTC)

To: Scott Duncan
From: Rosemary Godbold, Executive Secretary, AUTC
Date: 12 October 2012
Subject: Ethics Application Number 12/257 Associations among children's independent mobility, physical activity and cardio-metabolic risk factors.

Dear Scott

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 24 September 2012 and 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 by AUTC at its meeting on 29 October 2012.

Your ethics application is approved for a period of three years until 11 October 2015.

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

- A brief annual progress report using form EA2, which is available online through <http://www.aut.ac.nz/research/research-ethics/ethics>. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on ;
- A brief report on the status of the project using form EA3, which is available online through <http://www.aut.ac.nz/research/research-ethics/ethics>. This report is to be submitted either when the approval expires on or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTC is notified of any adverse events or if the research does not commence. AUTC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

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.

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 me by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 6902. Alternatively you may contact your AUTC Faculty Representative (a list with contact details may be found in the Ethics Knowledge Base at <http://www.aut.ac.nz/research/research-ethics/ethics>).

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

Yours sincerely

Dr Rosemary Godbold
Executive Secretary
Auckland University of Technology Ethics Committee

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Appendix C A pilot study exploring the measurement of intergenerational differences in independent mobility.

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A pilot study exploring the measurement of intergenerational differences in independent mobility



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ABSTRACT

Background: A fundamental issue limiting the understanding of children's independent mobility (IM) is the absence of a standardised measurement method. This pilot study explored the use of three different measures of IM to assess intergenerational change and investigated social perceptions in children's unsupervised roaming.

Methods: Data were collected for 45 participants from three directly-related generations. IM was assessed and analysed in all participants using three measures; IM Licence (permission to travel unsupervised), IM Index (the summed score from multiple items on a questionnaire) and IM Maximum (maximum roaming distance from participants' residential addresses located on Google Maps). Qualitative data were collected from all participants regarding perceptions of IM.

Results: Significant correlations between IM Index and IM Maximum were observed for child participants ($R^2=0.334$) but not for parents ($R^2=0.024$) or grandparents ($R^2=0.284$). IM Licence was not comparable with either IM Index or IM Maximum. Decreases in IM from grandparent to child were observed for all three measures of IM, with some children experiencing extremely low levels of IM.

Conclusion: The results highlight the need for a standard measurement protocol for IM that facilitates comparability among studies. Maximum IM distance estimated via web-based interactive mapping may be a promising choice in this respect.

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1. Introduction

Children with increased freedom to play and travel in their neighbourhood without adult supervision (independent mobility) (Hillman et al., 1990; Shaw et al., 2013; Broberg et al., 2013; Mammen et al., 2012) may experience numerous social and physical benefits (Hillman et al., 1990; Shaw et al., 2013; Mikkelsen and Christensen, 2009; Pooley et al., 2005). Independent mobility (IM) is fundamental to children's psycho-social development through the facilitation of cognitive skills (Burdette, 2005; Tamis-LeMonda et al., 2004), social prowess (Brown, 2009; Ginsburg, 2007) and emotional intelligence (Bunker, 1991). Children's IM also provides an important opportunity for the daily accumulation of physical activity that benefits children's short- (Brockman et al., 2010; Janz et al., 2010; Slutzky and Simpkins, 2009) and long-term (US Department of Health and Human Services, 1996; Habib and Saha, 2010; Blair et al., 2007) health. It has been suggested that children with reduced unsupervised exploration are missing out on opportunities to develop resilience and life-skills for the adult world (Gill, 2007; Mackett et al., 2007) and experience lower physical activity levels than those with increased IM (Brockman et al., 2010; Stone et al., 2014; Page et al., 2009; Wen et al., 2009; Ducheyne et al., 2012).

Despite the potential benefits of IM, investigation of children's IM over the last 40 years indicates a drastic intergenerational decline. Hillman et al. (1990) landmark study found substantial decreases in a range of English children's IM Licences (permission to roam on their own) from 1971 to 1990. These IM Licences reflected how children get around (on foot) on their own including licences to cross roads, to come home from school, to go places other than school and go out after dark. The IM Licences also related to the forms of transport

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available to young children; being able to cycle on public roads and use buses on their own. Two subsequent English studies conducted in 2000 (O'Brien et al., 2000) and 2010 (Shaw et al., 2013) using the same IM Licences found further decreases in children's independent roaming. Particularly noteworthy was the decrease in children aged 7–11 years old going home from school without adult supervision, which dropped from 86% in 1971 to 35% in 1990, decreasing further to 25% in 2010 (Shaw et al., 2013). Similar reductions have been found in other countries, including Germany (Shaw et al., 2013), the Netherlands (Karsten, 2005), Denmark, Finland, and Norway (Fyhri et al., 2011). Furthermore, recent studies in Australia (Veitch et al., 2008) and New Zealand (Freeman and Quigg, 2009) that have examined IM suggest that children today have very low levels of unsupervised roaming.

A number of pervasive social changes have propelled children's retreat from the streets. Exponential increases in global rates of car ownership have subsequently placed children at a persistent risk of enduring traffic related accidents (Collins and Kearns, 2001). A social trap has thus been created whereby concerned parents increasingly chauffeur their children by vehicle (Pooley et al., 2005), resulting in more traffic on the roads and fewer children on the streets. Additionally, neighbourhoods have experienced a reduction in social connections (Prezza and Pacilli, 2007), in part due to the increased ability to access areas further away from the local area; perceptions that neighbourhoods are less friendly have fuelled parental fear of strangers (Foster et al., 2014; Alparone and Pacilli, 2012). Media coverage of child abductions and crime has potentially amplified these fears, resulting in even less children roaming freely around local streets (Miller et al., 2008).

While several studies have investigated temporal changes in children's IM, it is difficult to compare findings due to heterogeneity in the ways IM has been defined and measured. Traditionally, children's IM has been assessed through self- or proxy-report of licences to roam unsupervised (Hillman et al., 1990; Shaw et al., 2013; Stone et al., 2014; Page et al., 2009; Ducheyne et al., 2012; Collins and Kearns, 2001; Pacilli et al., 2013; Tranter and Pawson, 2001; Veitch et al., 2014; Kytta, 2004). These licences reflect parental judgement of their child's ability to safely navigate the neighbourhood on their own. A key limitation of this method lies in the variation of how IM Licences are conceptually defined. Different aspects of IM Licences have been investigated including allowances (Hillman et al., 1990; Shaw et al., 2013; Tranter and Pawson, 2001), frequency of licences and destinations visited (Stone et al., 2014; Page et al., 2009; Pacilli et al., 2013), actualised affordances (Kytta, 2004) and territorial range (local and wider IM) (Page et al., 2009; Veitch et al., 2014). Consequently, comparability between these studies has some limitations. In addition, there have been inconsistencies between studies using IM Licences, in how the term *unsupervised* has been defined. In some studies there has been a focus on either a presence or absence of adult supervision (Hillman et al., 1990; Shaw et al., 2013; Ducheyne et al., 2012; Pacilli et al., 2013; Tranter and Pawson, 2001; Kytta, 2004) and some studies have incorporated the accompaniment of either siblings or friends in the definition of independent mobility (Stone et al., 2014; Page et al., 2009; Collins and Kearns, 2001; Veitch et al., 2014).

Assessment of active transport behaviours to and from school has also been used in previous studies as an IM indicator (Mammen et al., 2012; Mackett et al., 2007; Yang et al., 2014; Schoeppe et al., 2014; De Meester et al., 2014; Christian et al., 2014). The school journey provides a clearly defined episode of mobility, however it may not be undertaken independently. The school journey follows a route often predetermined by adults for which even active modes of transport may be supervised, such as through the use of walking school buses (Collins and Kearns, 2005).

Other studies have assessed children's real-time spatial movement via portable global positioning system (GPS) receivers (Mavoa et al., 2011; Quigg et al., 2010; Christensen et al., 2011; Barker et al., 2009). GPS receivers provide an objective measure of positional location and can accurately monitor individual journeys while removing participant bias (Stigell and Schantz, 2011; Duncan and Badland, 2009). However, a significant drawback of GPS is their inability to differentiate between supervised and non-supervised activity.

Map drawing is an alternative technique that has the potential to assess both children's licences to roam unsupervised in their neighbourhood, the distance they travel independently and to collect more complete data on the level of supervision. A number of studies exploring children's IM have utilised map drawing to facilitate the recall of travel licences (Veitch et al., 2008; Villanueva et al., 2013), perceived neighbourhood boundaries (Odgers et al., 2012), and roaming distances (Broberg et al., 2013; Freeman and Quigg, 2009; Badland et al., 2011). Recent advances in the development of online mapping have allowed a more interactive process that can assist in accurately recalling independent licences and distance travelled while acquiring further information on perceptions, experiences and environmental knowledge (Freeman and Quigg, 2009; Chaix et al., 2012; Kytta et al., 2012; Rissotto and Tonucci, 2002). Unlike static maps which previous studies have relied on (Veitch et al., 2008; Villanueva et al., 2013; Badland et al., 2011), an additional benefit of online mapping is that neighbourhood size is not predetermined or restricted. Although there are a number of benefits for using interactive mapping to assess children's IM, it is still in its infancy and there is currently an absence of a single standard definition of IM using this method.

It is apparent that a significant issue limiting the understanding of children's IM is the variability in the conception definition of IM and the absence of a standardised measurement method. There is the need to understand differences and relationships between different measures of IM and whether these vary from child and parent perspectives. The aims of this pilot study were to (1) explore the use and comparability of three different measurement techniques to assess current and historical changes in children's IM over three directly related generations and (2) to assess the social perceptions potentially limiting children's IM today.

2. Methodology

This cross-sectional pilot study was conducted in Auckland, New Zealand in August 2011 using a mixed methods approach. Written, informed consent and assent were required prior to participating in the study. Ethical approval was obtained from the AUT Ethics Committee (AUTC 11/121).

2.1. Participants

A convenience sample of participants was recruited through existing professional and personal contacts. Participants who met the eligibility criteria were invited to participate and provided written informed consent and assent. Children aged 10–12 years old were eligible; inclusion criteria for the parents and grandparent were to be gender-matched and directly related through the same genetic line as the child participant.

2.2. Procedures

Data were collected in each participant's home by a trained researcher; in the first instance with the child and parent, and in the second instance with the grandparent. Each participant took part in a semi-structured interview which included demographic questions, three measures of IM, and questions regarding perceptions of IM. The children's data were collected independently, without the presence of their adult relatives.

2.3. Measures

Demographic information was collected during the adult interviews. The number of working vehicles, bicycles and child mobile phone ownership was determined. The researcher made notes in regards to urban design including the type of house, street and if there was a back garden.

For all IM measures the child participants reported their current IM allowances and mobility. The parent and grandparent participants recalled their experiences as a 10–12 year old. To assess IM Licence, each participant was asked if they were allowed to go out on their own in the local neighbourhood. They were given the following options as responses: (1) yes, (2) no – only with other children, (3) no – only with an older sibling and (4) no – only with an adult. If 'yes' was answered, participants were then asked "If yes – is there/was there a time limit you are allowed out for". The children's and adults responses were cross referenced by asking the parent/guardian the same question in context "Was your child allowed to go out on his or her own in the local neighbourhood?".

Participants' degree of independent roaming in their neighbourhood was assessed using a questionnaire previously used in another international study to measure children's IM (Page et al., 2009). They were asked "how often are you allowed to go to the following places on your own or with friends (without an adult)?" For each location (local shops, big shopping centre, park, sports centre, swimming pool, library, school, cinema, friend's house, other outdoor places [beach, river, bush], bus stop or train station and local streets) participants were given the following scale to choose from: never, sometimes, often, or always. Participants were given an additional option of "I do not go there" for locations that are not available in the area. Each of the responses was assigned a rank (Never = 0, Sometimes = 1, Often = 2, Always = 3) and then summed to give a total score. The summed total was divided by the number of places the participant went to (excluding those answered "I do not go there"), which gave an overall IM Index.

Participants' maximum unsupervised roaming distance (IM Maximum) was assessed through the use of a computer assisted personal interview (CAPI), which took approximately five minutes. Using a laptop computer running the online application Google Maps, participants were assisted to plot their home and then identify the location which was the greatest distance from their home that they were allowed to roam unsupervised (without adult supervision or accompanied by friends/siblings). Using the mapping functions of the Google Maps software, the distance between this maximum roaming point and the participant's home was measured using the street network and following the most habitual route typically taken for this journey.

Participants' viewpoints and attitudes regarding children's current and historical IM were gathered during the semi-structured interviews. Key interview questions to engage conversation around parents and grandparents perspectives included: "are there (or were there) any reasons why your child is not allowed to go to certain places on their own?" and "do you think there is anything different from when you were 10–12 years old for your children today?". Questions for children included: "is there any reason why you do not like to go to certain places on your own?", "what do you think are your parents' reasons?" and "if you were allowed is there anywhere else you would like to go?"

2.4. Data analysis

Means and standard deviations for all descriptive data were calculated and differences between sexes examined using independent samples *t*-tests. One-way analysis of variance procedures with post-hoc testing was used to investigate differences in IM Index and IM Maximum among the three generations. Statistical significance was calculated using $P < 0.05$. Pearson correlations and regression analysis were conducted to assess the similarity between IM Index and IM Maximum. All analyses were conducted on SPSS (V. 17). No statistical comparisons were made between IM Licence and IM Index/IM Maximum, due to heavily skewed IM Licence data (see Section 3). Interview questions regarding perceptions were systematically analysed by generation for common themes.

Table 1
IM Index and IM Maximum for all participants and by gender.

		N	IM Maximum	IM Index
Child	Male	14	2796 (1281)	1.54 (0.59)
	Female	7	2428 (2957)	1.38 (0.9)
	Total	21	2673 (1929)*	1.49 (0.7)*
Parent	Male	8	7025 (6508)	2.4 (0.44)
	Female	9	3833 (2522)	2.1 (0.45)
	Total	17	5335 (4940)**	2.28 (0.44)**
Grandparent	Male	4	12,400 (5757)	2.75 (0.10)
	Female	3	1690 (1293)	2.26 (0.15)
	Total	7	7810 (7064)	2.54 (0.28)

* Significantly different from parents and grandparents ($P < 0.05$).

** Significantly different from grandparents ($P < 0.05$).

3. Results

A total of 21 children aged 10–12 years (14 male, 7 female), 17 parents aged 34–51 years (8 male, 9 female), and seven grandparents aged 62–73 years (4 male, 3 female) participated in the study. The majority of children (90%) lived in a single detached dwelling; two child participants lived in a unit. The children's homes were situated either on a residential street (66%) or a cul-de-sac (33%) and most (81%) had a back garden. Each family had an average of two vehicles and 4.6 bikes per household. Over half (62%) of the children owned a cell phone. The average number of children per household was 1.6 and 38% of the children had older siblings.

3.1. Independent mobility

3.1.1. IM Index and IM Maximum

Table 1 shows the IM Index and IM Maximum for the study sample. Mean IM Index for children was 1.49 (SD=0.7), parents 2.28 (SD=0.44) and grandparents 2.54 (SD=0.28). Males had a higher IM Index than females across all generations. While the mean IM Index decreased generationally from grandparents to parents to children, the difference was significant between parents and children only ($P < 0.01$). The mean IM Maximum travelled by children was 2673 m (SD=1929) and ranged from 200 to 7000 m. The mean IM Maximum travelled by adult participants was 5335 (SD=4940) and ranged from 1500 to 22,000 m. Mean IM Maximum for grandparent participants was 7810 (SD=7064) and ranged from 270 to 17,000 m. Males had consistently higher IM Maximum than females across all generations. As with IM Index, generational differences in mean IM Maximum were significant between parents and children only ($P=0.029$).

Fig. 1 illustrates the relationship between IM Maximum and IM Index for children, parents, and grandparents. A significant correlation was observed between IM Maximum and IM Index for children ($\rho=0.568$, $P=0.007$) and across the pooled dataset ($\rho=0.452$, $P=0.002$), but not for parents ($\rho=0.117$, $P=0.655$) or grandparents ($\rho=0.741$, $P=0.057$). Regression analysis revealed a significant linear trend between IM Maximum and IM Index in the child group (IM Maximum = $1.60 \times \text{IM Index} + 0.289$, $R^2=0.334$, $P=0.006$), but not for the parent (IM Maximum = $1.73 \times \text{IM Index} + 1.38$, $R^2=0.024$, $P=0.550$) or the grandparent group (IM Maximum = $15.9 \times \text{IM Index} - 32.6$, $R^2=0.284$, $P=0.126$). The regression model for the pooled data (displayed in Fig. 1) showed a significant linear trend (IM Maximum = $2.92 \times \text{IM Index} - 1.23$, $R^2=0.205$, $P=0.002$).

3.1.2. IM Licence

Grandparents and adults reported similar IM Licences: all were allowed out in the neighbourhood on their own with minimal restrictions. The time limits put in place were either 'to be home for dinner' or 'by dark'. Of the child participants, 17 children (12 males and 5 female) were allowed in the neighbourhood on their own but experienced considerable restrictions around where they could or could not play. Six (28%) of the child participants were only allowed out for a set time between 30 min and 1 h and then were required to be home. Ten of the child participants were allowed out on their own if the location was prearranged and parents knew what time they would be home. Of the children that had access to a cell phone ($n=8$), they were all required to use these to keep in regular contact with their parents. One male child participant had complete freedom to go anywhere in the neighbourhood on their own and did not have any restrictions in regards to location of play or the amount of time they were out for. Four child participants (2 males and 2 females) were not allowed out on their own at all unless they were accompanied by either a sibling ($n=1$) or a friend ($n=3$). In addition, each of these children had to get prior approval from their parents as the length of time they would be out for, who they were going with and exactly where they were going. Due to the low numbers of participants who were not permitted to travel without adult supervision, meaningful comparisons between IM Licence and IM Index/IM Maximum were not possible.

3.2. Qualitative interviews

There were particular themes that emerged in response to key questions asked in the semi-structured interviews for each generation; relevant quotes have been included to emphasise these themes.

3.2.1. Grandparents

When asked if there were any reasons why they were not allowed to go to certain places either for themselves as 10–12 year olds or for their children (parent participants), none of the grandparent participants recalled any restrictions other than needing to be home by dinner.

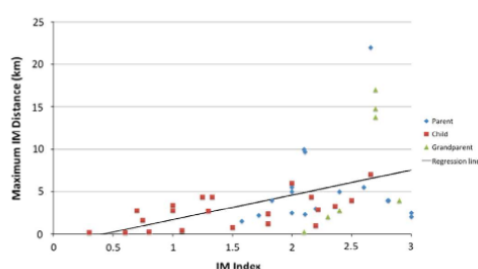


Fig. 1. Association between IM Maximum and IM Index for children, parents, and grandparent. The linear regression line was fitted to data from all three groups.

“Just needed to be home in time for dinner, we just played in the street with other kids so did not need to travel far” (Grandparent in response to their own childhood).

All grandparent participants noted drastic changes in the neighbourhood from when they were children to that of their grandchildren today. The significant rise in traffic volume, greater access to drugs, a decrease in neighbourhood sociability, and increased risk of stranger danger were all common changes mentioned. In addition, there was an overall view that children today are very sheltered or (to quote) ‘mollycoddled’.

“We used to have an open door all the time with people coming in – we never dreamed there would be a day where we would be locking the door with us inside!” (Grandparent participant).

“The biggest different today is that we do not know our neighbours – it took an earthquake for people to start talking to each other” (Grandparent participant).

3.2.2. Parents

None of the parent participants could recall any reasons why they were restricted from certain places as a child other than needing to let their parents know generally where they were going and to be home by dark. In regards to perceived changes from when they were 10–12-year-old children, parents’ responses were similar to the grandparents’. The changes most frequently discussed were an increase in traffic volume, speed that vehicles travel, threat of violence, and access to drugs. A decrease in neighbourhood sociability, a change in family structure with both parents working, and a rise in organised sport was also commonly mentioned.

In response to the question “are there any reasons why your child is not allowed to go out on their own or to certain places in the local neighbourhood?”, 90% of parents brought up concerns of safety. When analysed for common themes, traffic (62%), stranger danger (47%), darkness (28%), and general safety (28%) were the most common reasons why parents do not allow their children out on their own.

“Yes – (he is allowed out on his own) but everything must be prearranged, the route to school is prearranged and he has his cell phone. If he is not home by 4pm I worry” (Parent of an 11 year old boy).

3.2.3. Children

All child participants were aware of the reasons their parents restricted them from going to certain places (safety, traffic, or strangers). However, 71% of the children had no concerns about travelling to certain places on their own. Of those that did have concerns, all responded with a fear of strangers, and two child participants mentioned a fear of traffic related accidents. The majority of children (76%) could identify places they would like to go to if they were allowed. The places most frequently mentioned were shopping malls, movies, and friends’ houses. There were no significant gender differences.

“My parents are concerned about my safety but I feel independent enough” (male, 11-year old).

“Mum knows I can look after myself but I guess roads are busy” (female, 11-year old).

4. Discussion

Children’s IM is a growing research field where by differences in measurement procedures and definitions of IM currently hinders further understanding. The primary purpose of this pilot study was to explore and compare three measures of children’s IM across three generations. Each of the measures implemented (IM Licence, IM Maximum and IM Index) were feasible and acceptable for all participants to use irrespective of age and gender. The self-reported nature of the IM Licence and IM Index means the questions could be used as part of a larger survey or questionnaire, subsequently offering a low cost, quantifiable measure of children’s independent mobility applicable for large sample sizes (Hillman et al., 1990; Shaw et al., 2013; Page et al., 2009).

However, as with previous studies, the complexity in conceptual definition of IM Licences has limited the comparability of IM Licence as a measure. The decision for parents and caregivers to grant IM Licences is rarely a ‘yes’ or ‘no’ decision. There are contingencies which affect their decision-making in certain circumstances (Mikkelsen and Christensen, 2009). This was apparent through the responses to IM Licence questions and the semi-structured interviews, whereby there was variation in the rules around the allowances given for children today including set time frames, companionship, pre-arranged locations and the use of a cell phone for ongoing parental contact. These data would support the need for a differentiated measure of children’s IM which accounts for the extent in which children’s independence can vary.

The IM Maximum utilised map drawing methodology similar to previous studies (Veitch et al., 2008; Freeman and Quigg, 2009) yet with a specific quantifiable variable. The mapping methodology provided an interactive experience for participants and the various functions of Google Maps, including the identification of key landmarks, zooming options and ‘street view’ perspectives, likely aided participants’ recall. In addition, the data were easily interpretable, a limitation previously identified for static mapping techniques (Badland et al., 2011). While the estimates of IM Index and IM Maximum were significantly correlated, the proportion of explained variance (R^2) ranged from 2.4% (n.s) in parents to 33.4% in children. These findings suggest that to a certain extent these measures are conceptually related, i.e. the maximum roaming distance may directly influence choice of destinations and the frequency visited (or vice versa). However, there is a need for academic consensus on the definition and measurement of IM to facilitate comparability and accurate interpretation of future studies. It is our recommendation that the use of web-based interactive mapping offers the greatest potential to provide an accurate and in-depth measure of children’s current IM distance, including possible inhibitors and enhancers of autonomous movement in the neighbourhood.

Our results also indicated substantial generational decreases in all measures of IM (IM Licence, IM Maximum and IM Index). Mean IM Index levels and mean IM Maximum decreased slightly (but non-significantly) between grandparents to parents, with relatively large decreases from parents to children. Only one child from today’s generation was permitted the same unrestricted licence to roam and travel freely in the neighbourhood that their parents and grandparents experienced. These findings align with earlier research (Hillman et al., 1990; Shaw et al., 2013; O’Brien et al., 2000; Fyhri et al., 2011) that indicates children today experience much less freedom to play and explore their neighbourhood as their parents and grandparents did at the same age.

In regards to IM levels of children today, the findings of this study parallel current research. Children's mean IM Maximum was 2673 m (± 1929). Another New Zealand pilot study investigating the measurement of IM in 17 children aged between 5 and 12 found similar maximum roaming distances (Badland et al., 2011). It was also noted that some children had very low levels of IM; three children in this study had a maximum roaming distance of 250 m or less. In some instances children experienced severe restrictions on their play; for example, some children were required to have their outing prearranged at a designated location, or were confined to a 30 min time limit. Similar results were found in an Australian study of 212 children aged 8–12 years old, with 32% of the participants having an IM range less than 100 m, and 12% of all children not being allowed to walk or cycle without an adult (Veitch et al., 2008). Likewise, in a recent Canadian study of 856 children (10–12 years old), where parents were asked how often their child is allowed out without adult supervision (either on their own or with a friend), nearly 40% of the participants were never allowed out without an adult (Stone et al., 2014). While the long-term developmental effects of such low levels of IM are uncertain, there is emerging evidence to suggest that low IM may negatively impact children's physical and psycho-social development (Brockman et al., 2010; Page et al., 2009; Martínez-Gómez et al., 2011).

Previous research has reported consistent evidence that boys are granted more IM than females (Hillman et al., 1990; O'Brien et al., 2000; Tranter and Pawson, 2001; Kytta, 2004; Badland et al., 2011). It is understood that the reasoning behind this is twofold: that parents are more concerned with their daughter's safety, and that girls are encouraged to take up household responsibilities to a greater extent than boys (Valentine and McKendrick, 1997). While gender differences were apparent in parents and grandparents in the present study, there was little variation in the IM levels between genders in the child participants. It is possible that as children's IM levels drop to a very low level gender differences experienced previously will no longer be apparent. Indeed, one of the most recent studies in this area was unable to find differences in IM between boys and girls (Shaw et al., 2013).

The qualitative findings from this study demonstrate that for previous generations, parents had little or no concerns about their children roaming freely in the neighbourhood. By comparison, parents today expressed a number of concerns for their children's safety, especially in regards to traffic and 'stranger danger'. These fears have been well noted in previous literature as significant reasons why children's IM is restricted today (Foster et al., 2014; Tranter and Pawson, 2001; Carver et al., 2005; Prezza et al., 2001; Veitch et al., 2006). It is highly likely that parental concern for their child's safety and the change in neighbourhood sociability have resulted in children's IM Licences and independent roaming being more restricted. Conversely, children in this study did not share the same concerns regarding their safety as their parents. They expressed a desire to have more autonomous roaming and frustration at feeling capable to negotiate the neighbourhood safely while being heavily restricted from this. These findings are comparable to those from a study conducted in Australia (Tandy, 1999) and other another New Zealand study examining children's perspectives on their IM (Mitchell et al., 2007).

Given the exploratory nature of this pilot study and the small sample size, caution needs to be taken when making generalisations. In addition, the former home addresses of some of the grandparents had changed from a rural area to an urban area, and in some instances were difficult to locate exactly on Google Maps. It is possible this limited the recall ability for this generation. Finally, it was more difficult to recruit grandparent participants compared to child and parent participants due to unavailability, resulting in a proportionately lower sample size; this could potentially present sampling bias issues in future studies.

5. Conclusion

In conclusion, all measures of IM utilised in this pilot study were feasible and practical to use across three directly related generations. The suggested correlation between IM Index and IM Maximum is worth exploring further, especially the use of interactive mapping technology given the potential to accurately measure various important facets of children's IM. The findings that children's autonomous movement has declined significantly from earlier generations are concerning and further research is warranted to investigate possible associations with aspects of children's health.

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CHILDREN'S QUESTIONNAIRE

This questionnaire asks you to report on activities that you do for fun and play. There are also some questions about how you are allowed to travel to certain places. Please read the instructions at the start of each section carefully. You do not need to answer any questions that you do not feel comfortable answering.



Demographic Questions

1 Are you?
☐ Male ☐ Female

2 Year of birth

3 Ethnicity or ethnicities

4 How many siblings do you have?
 siblings
 → Please list their ages:

Current Activity

The following questions relate to your current activity – these questions will ask you about the time you spent being physically active in the **last 7 days**. Do not include activity undertaken today. By 'active' I mean doing anything using your muscles. Think about activities at school or home, getting from place to place, and any activities you did for exercise, sport, or fun.

5 During the last 7 days, on how many days did you **walk** at a brisk pace – a brisk pace is a pace at which you are breathing harder than normal?
This includes walking at school, while getting from place to place, at home and at any activities that you did for sport, exercise or fun.
 Think only about brisk walking done for at least 10 min at a time
 days per week
 None → Go to **7**

6 How much time did you typically spend **walking** at a brisk pace on each of those days?
 hours
 minutes

7 During the last 7 days, on how many days did you do **moderate** physical activities?
'Moderate' activities make you breathe harder than normal, but only a little – like climbing trees, dancing, cycling, cricket, skate boarding, horse riding. Do not include walking of any kind.
 Think only about those physical activities done for at least 10 min at a time
 days per week
 None → Go to **9**

8 How much time did you typically spend on each of those days doing **moderate** physical activities?
 hours
 minutes

9 During the last 7 days, on how many days did you do **vigorous** physical activities?
'Vigorous' activities make you breathe a lot harder than normal ('huff and puff') – like running, swimming, mountain biking, judo, netball, rugby.
 Think only about those physical activities done for at least 10 min at a time
 days per week
 None → Go to **11**

10 How much time did you typically spend on each of those days doing **vigorous** physical activities?
 hours
 minutes

11 During the last full week (Monday to Sunday), what organised sport or other activities (such as dance, gym, swimming) did you do each day?

Mon	
Tues	
Wed	
Thurs	
Fri	
Sat	
Sun	

Questions continue on following page

Screen time

These questions relate to the time you spend sitting in front of a screen. Think about the average time you spent in screen time over the **last 7 days**. By screen time I mean time spent in front of the television, computer, playstation, iPad (or any other electronic equipment).

*Do **not** include time spent at school.*

- 12** In the past week, how much time each day (on average) did you spend in front of a screen (TV, computer, iPad, PS3 etc) **during the week** (Monday-Friday)?

<input type="checkbox"/> None	<input type="checkbox"/> 2 hours
<input type="checkbox"/> 15 minutes	<input type="checkbox"/> 3 hours
<input type="checkbox"/> 30 minutes	<input type="checkbox"/> 4 or more hours
<input type="checkbox"/> 1 hour	→ hours

- 13** In the past week, how much time each day (on average) did you spend in front of a screen (TV, computer, iPad, PS3 etc) on **weekends** (Saturday-Sunday)?

<input type="checkbox"/> None	<input type="checkbox"/> 2 hours
<input type="checkbox"/> 15 minutes	<input type="checkbox"/> 3 hours
<input type="checkbox"/> 30 minutes	<input type="checkbox"/> 4 or more hours
<input type="checkbox"/> 1 hour	→ hours

School Transport

- 14** How do you usually travel **to** school

☐ Walk
☐ Car
☐ Cycle
☐ Scooter
☐ Bus
☐ Other

- 15** Who do you usually go **to** school with?

☐ On your own
☐ Adult
☐ Sibling
☐ Friend
☐ Other

- 16** How do you usually travel **from** school?

☐ Walk
☐ Car
☐ Cycle
☐ Scooter
☐ Bus
☐ Other

- 17** Who do you usually go **from** school with?

☐ On your own
☐ Adult
☐ Sibling
☐ Friend
☐ Other

Rules

- 18** Are you allowed to do the following activities **without an adult**:

Either by yourself, with your brother or sister, or with friends.

	Yes	No	Unsure
Go to school	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Go from school	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cross main roads	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cycle main roads	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Go on a bus or train	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Go out after dark	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Destinations

- 19** How often do you parents let you travel to the following destinations **without an adult**:

Either by yourself, with your brother or sister, or with friends.

	Never	Sometimes	Often	Always	I do not go there
Local shops	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Big shopping centre	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Park or playground	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sports centre	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Swimming pool	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Library	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
School	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Movies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Friend's house	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other outdoor places	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bus stop or train station	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nearby streets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

PARENT/GUARDIAN QUESTIONNAIRE

This anonymous questionnaire asks you to report on your play and roaming activities that you did as a 10-12 year old. There are also some questions regarding your current physical activity and screen time activities. Please read the instructions at the start of each section carefully. You do not need to answer any questions that you do not feel comfortable answering.

Demographic Questions

1 What gender are you?
☐ Male ☐ Female

2 Year of birth

3 Ethnicity or ethnicities

4 What is your home address?
Will only be used to see how far you live from school

5 How many people (including yourself) live in your household?
 people

6 How many children live in your household?
 children
 → Please list their ages:

7 What was the highest education level you completed?
☐ Finished primary school
☐ Finished secondary school
☐ University Entrance/ Bursary/Scholarship
☐ Apprenticeship, diploma, trade certificate
☐ Bachelor degree or higher

8 What type of residence do you live in?
☐ Single family house
☐ Multi-family house
☐ Apartment
☐ Townhouse/unit
☐ Other

9 How many hours per week do you spend in paid employment?
 hours per week

10 How many driveable motor vehicles (cars, motorcycles) are there at your household?
 motor vehicles

11 How many bicycles are at your household?
 bicycles

The following questions relate to when you were a child aged 10-12 years old.

12 What was the address you lived at when you were in Forms 1 and 2 (10-12 years of age)?
New Zealand address only.
If you lived at more than one address, please choose the one where you spent the most time.

13 When you lived at the above address, what was the school you went to in Forms 1 and 2?

14 How many motor vehicles did you household have when you were 10-12 years of age?
 motor vehicles

15 How many bicycles did you household have when you were 10-12 years of age?
 bicycles

16 During a typical summer what were the organised sports or other organised activities that you did as a 10-12 year old?
Such as cricket, dance, gym, swimming

17 During a typical winter what were the organised sports or other organised activities that you did as a 10-12 year old?
Such as rugby, soccer, dance, gym, swimming

Questions continue on following page

School Transport

18 When you were in Forms 1 and 2 how did you usually travel to school?

- ☐ Walk
☐ Car
☐ Cycle
☐ Bus
☐ Other

19 When you were in Forms 1 and 2 who did you usually go to school with?

- ☐ On your own
☐ Adult
☐ Sibling
☐ Friend
☐ Other

20 When you were in Forms 1 and 2 how did you usually travel from school?

- ☐ Walk
☐ Car
☐ Cycle
☐ Bus
☐ Other

21 When you were in Forms 1 and 2 who did you usually go from school with?

- ☐ On your own
☐ Adult
☐ Sibling
☐ Friend
☐ Other

Rules

22 When you were 10-12 years of age, were you allowed to do the following activities without an adult:

Either by yourself, with your brother or sister, or with friends.

	Yes	No	Unsure
Go to school	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Go from school	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cross main roads	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cycle main roads	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Go on a bus or train	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Go out after dark	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Destinations

23 When you were 10-12 years of age, how often did your parents let you travel to the following destinations by yourself, with your brother or sister, or with friends, but without an adult?

If the places did not exist, please tick 'I did not go there'

	Never	Sometimes	Often	Always	I did not go there
Local shops	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Big shopping centre	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Park or playground	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sports centre	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Swimming pool	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Library	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
School	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Movies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Friend's house	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other outdoor places	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bus stop or train station	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nearby streets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Questions continue on following page

Current Activity

The following questions relate to your current activity **as an adult** – these questions will ask you about the time you spent being physically active in the **last 7 days**. Do not include activity undertaken today. By 'active' I mean doing anything using your muscles. Think about activities at work, school or home, getting from place to place, and any activities you did for exercise, sport, or leisure.

- 24** During the last 7 days, on how many days did you walk at a brisk pace – a brisk pace is a pace at which you are breathing harder than normal?

This includes walking at work or school, while getting from place to place, at home and at any activities that you did solely for recreation, sport, exercise or leisure.

Think only about brisk walking done for at least 10 min at a time

days per week

None → Go to **26**

- 25** How much time did you typically spend walking at a brisk pace on each of those days?

hours

minutes

- 26** During the last 7 days, on how many days did you do moderate physical activities?

'Moderate' activities make you breathe harder than normal, but only a little – like carrying light loads, bicycling at a regular pace, lawn mowing, cricket, cycling or farming. Do not include walking of any kind.

Think only about those physical activities done for at least 10 min at a time

days per week

None → Go to **28**

- 27** How much time did you typically spend on each of those days doing moderate physical activities?

hours

minutes

- 28** During the last 7 days, on how many days did you do vigorous physical activities?

'Vigorous' activities make you breathe a lot harder than normal ('huff and puff') – like heavy lifting, digging, aerobics, fast bicycling, tramping, triathlon, netball or rugby.

Think only about those physical activities done for at least 10 min at a time

days per week

None → Go to **30**

- 29** How much time did you typically spend on each of those days doing vigorous physical activities?

hours

minutes

- 30** Thinking about all your activities over the last 7 days (including brisk walking), on how many days did you engage in:

• At least 30 minutes of moderate activity (including brisk walking) that made you breathe a little harder than normal,
OR

• At least 15 minutes of vigorous activity that made you breathe a lot harder than normal ('huff and puff')?

days per week

Screen time

These questions relate to the time you spend sitting in front of a screen **as an adult**. Think about the average time you spent in screen time over the **last 7 days**. By screen time I mean time spent in front of the television, computer, playstation, iPad (or any other electronic equipment).

Do **not** include time spent at work.

- 31** In the past week, how much time each day (on average) did you spend in front of a screen (TV, computer, iPad, PS3 etc) **during the week** (Monday-Friday)?

None

15 minutes

30 minutes

1 hour

2 hours

3 hours

4 or more hours hours

- 32** In the past week, how much time each day (on average) did you spend in front of a screen (TV, computer, iPad, PS3 etc) on **weekends** (Saturday-Sunday)?

None

15 minutes

30 minutes

1 hour

2 hours

3 hours

4 or more hours hours

Questions continue on following page

Decisions with risk

33

The following sentences describe how various people deal with risky situations and what their attitudes toward risky decisions are. Could you please read each sentence and then rate to what extent that statement is true for you.

For your answers, a seven-point scale is provided:

	No, not at all				True for me			Very much so
	1	2	3	4	5	6	7	
I'm quite cautious when I make plans and act on them.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I follow the motto 'nothing ventured, nothing gained.'	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I have sympathy for adventurous decisions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
If a task seems interesting I'll choose to do it even if I'm not sure whether I'll manage it.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I don't like to put something at stake; I would rather be on the safe side.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Even when I know that my chances are limited I try my luck.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
In my work I only set small goals so that I can achieve them without difficulty.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I express my opinion even if most people have opposite views.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
My decisions are always made carefully and accurately.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I would like to act in my boss's job some time so as to demonstrate my competence, despite of the risk of making mistakes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I tend to imagine the unfavourable outcomes of my actions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Success makes me take higher risks.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Thank you for taking the time to complete this anonymous questionnaire.

Please ensure that your child returns this to their school.