The Contribution of the Neighbourhood Environment to the Relationship between Neighbourhood Disadvantage and Physical Function Among Middle-aged to Older Adults

by

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This thesis is submitted in total fulfilment of the requirements for the degree of Doctor of Philosophy in the Institute for Health & Ageing,

Australian Catholic University

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DECLARATION

This thesis contains no material that has been extracted in whole or in part from a thesis that I have submitted towards the award of any other degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgment in the main text of the thesis.

All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committees (where required).

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Publications and awards

Journal articles relevant to the thesis

Loh VH, Rachele JN, Brown WJ, Washington S, Turrell G. 2016. Neighbourhood disadvantage, individual-level socioeconomic position and physical function: A cross-sectional multilevel analysis. *Prev Med* 89:112-120.

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Journal articles published during my candidature

Rachele JN, Ghani F, **Loh VH**, Brown WJ, Turrell G. 2016. Associations between physical activity and the neighbourhood social environment: Baseline results from the habitat multilevel study. *Prev Med* 93:219-225.

Backholer K, Sarink D, Beauchamp A, Keating C, **Loh V**, Ball K, et al. 2016. The impact of a tax on sugar-sweetened beverages according to socio-economic position: A systematic review of the evidence. *Public Health Nut*r 1-15.

Awards

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Poster Presenter at Institute for Health and Biomedical Innovation (IHBI) Inspires Postgraduate Conference, Queensland University of Technology, Brisbane, Australia. “Cumulative physical activity as the mediator between neighbourhood disadvantage and physical function”. ***(Loh, VH**, Rachele JN, Brown WJ, Washington S, Turrell G)*

2014 Poster Presenter at Institute for Health and Biomedical Innovation (IHBI) Inspires Postgraduate Conference, Queensland University of Technology, Gold Coast, Australia. “Neighbourhood disadvantage, individual-level socioeconomic position and physical function”. ***(Loh, VH**, Rachele JN, Brown WJ, Washington S, Turrell G)*

Media output

2017 Rachele, JN, Sallis, JF, **Loh V**. “Eight simple changes to our neighbourhoods can help us age well.” *The Conversation* 12 Oct 2017. http://theconversation.com/eight-simple-changes-to-our-neighbourhoods-can-help-us-age-well-83962

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To my PhD backbone

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List of abbreviations

ABS	Australian Bureau of Statistics
ACU	Australian Catholic University
ALSWH	Australian Longitudinal Study on Women's Health
ANEWS	Abbreviated Neighbourhood Environment Walkability Scale
ANOVA	Analysis of Variance
AQF	Australian Qualification Framework
ASCO	Australian Standard Classification of Occupation
BMI	Body Mass Index
CBD	Central Business District
CCD	Central Collector District
CI	Confidence Interval
CRE	Centre for Research Excellence
CrI	Credible Interval
DAG	Directed Acyclic Graph
EBE	Empirical Bayes Exchangeable
GIS	Geographic Information System
HABITAT	How Areas in Brisbane Influence Activity and Health
IRSD	Index of Relative Socioeconomic Disadvantage
LTPA	Leisure-time Physical Activity
MLLR	Multilevel Linear Regression
MLMLR	Multilevel Multinomial Logistic Regression
NHMRC	National Health and Medical Research Council
NPSC	Neighbourhood-level Perceptions of Safety from Crime
OR	Odds Ratio
PCA	Principal Component Analysis

PF-10	Physical Function-10
SD	Standard Deviation
SEP	Socioeconomic Position
SF-36	Short Form-36
STATA	Statistics and data software
TRPA	Transport-related Physical Activity
UK	United Kingdom
US	United States
VPC	Variance Partition Coefficient
WfR	Walking for Recreation
WfT	Walking for Transport

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Abstract

Background

With the continuing increases in life expectancies in developed countries, an important public health goal is to ensure successful ageing—morbidity compression, maintenance of physical functioning and active engagement in life. It is well established that the onset of physical function decline begins in mid-life, and functional capacity is critical to maintaining mobility, independence and quality of life. A growing body of literature has found that residents of more disadvantaged neighbourhoods have significantly poorer physical function, independent of individual-level factors. However, the mechanisms through which neighbourhood environments are associated with this relationship remain largely unknown.

The overarching aim of this thesis was to investigate the contributions of the neighbourhood environment to the relationship between neighbourhood disadvantage and physical function among middle-aged to older adults: this was accomplished in three studies. First, I examined the relationship between neighbourhood disadvantage and physical function in the Australian context (Study One). Second, I investigated if this relationship is explained by neighbourhood-level perceptions of safety from crime and walking for recreation (Study Two). Third, I examined the contribution of neighbourhood walkability and walking for transport to the relationship between neighbourhood disadvantage and physical function (Study Three).

Methods

This program of research utilized secondary data from the How Areas in Brisbane Influence HealTh and AcTivity (HABITAT) study. HABITAT is a multilevel

longitudinal study underpinned by a social ecological framework. It was conducted in Brisbane among adults aged 45-70 years living in 200 neighbourhoods. HABITAT commenced in 2007 and had subsequent data collection waves in 2009, 2011, 2013 and 2016. For this thesis, the 2013 data were utilised as physical function was first collected in 2013 (n= 6,520). The measure of neighbourhood disadvantage was derived from the Australian Bureau of Statistics' (ABS) Index of Relative Socioeconomic Disadvantage (IRSD) scores. Physical function was measured using the Physical Function Scale (0 – 100), a component of the Short Form-36 Health Survey, with higher scores indicating better function. In Study Two, participants self-reported their perceptions of safety from crime using items from the Neighbourhood Environment Walkability Scale (NEWS) questionnaire, which were subsequently aggregated to the neighbourhood-level. Walking for recreation (minutes per week) was self-reported by participants. In Study Three, neighbourhood walkability measures (street connectivity, dwelling density and land use mix) was objectively measured and provided by the Brisbane City Council (the local government authority responsible for the jurisdiction covered by the HABITAT study). Walking for transport (minutes per week) was self-reported by participants.

The data were analysed using multilevel regression models (linear, binomial or multinomial). In instances where multilevel categorical models are undertaken, Markov chain Monte Carlo (MCMC) simulation will be employed to estimate odds ratio and 95% credible intervals. All data were prepared in STATA SE 13 and analyses were conducted using MLwiN version 2.35.

Results

Findings from Study One found that residents of more disadvantaged neighbourhoods had significantly poorer physical function. These associations remained significant after adjustment for individual-level socioeconomic position (SEP). Moving forward from the descriptive findings, Study Two found that neighbourhood-level perceptions of safety from crime and walking for recreation partly explained (24% in men and 25% in women) neighbourhood differences in physical function. In Study Three, I found that neighbourhood walkability and walking for transport did not explain the relationship between neighbourhood disadvantage and physical function.

Conclusion

Given the growing proportion of the ageing population in Australia and the resultant increasing pressure on neighbourhood and city infrastructure in Australia, it is important to understand the contributions of the neighbourhood environment in the relationship between neighbourhood disadvantage and physical function. Despite the complexity in understanding neighbourhood socioeconomic differences in physical function, the findings of this thesis suggest that the neighbourhood in which we live is important to physical function. To reduce neighbourhood inequalities in physical function, attention needs to be given to improve the perceptions of safety from crime in more disadvantaged neighbourhoods to encourage more walking for recreation. Living in a walkable neighbourhood is important to support more walking for transport, but may not be sufficient to reduce neighbourhood inequalities in physical function. A multi-faceted intervention is needed to create a healthy, liveable and equitable community for successful ageing.

KEYWORDS: neighbourhood disadvantage, physical function, health inequalities, ageing, social environment, walking, built environment, multilevel modelling.

CHAPTER 1: INTRODUCTION

Health and inequalities in health are closely linked to the conditions in which we raise our children, the education we get, the neighbourhoods in which we live, the work we do, whether we have the money to make ends meet, our social relationships, and our care for the elderly. In short, all the things that matter to us day to day and in the arc of our lives influence health. And these conditions of life that matters to us are strongly influenced by the decisions that societies make and, indeed, global decisions that influence our social environment.

Marmot [1]

1.1 Background

1.1.1 Social inequalities in health

Health is improving globally. Advances in medicine coupled with urbanisation and globalisation have substantially reduced rates of mortality and morbidity [2]. In many developed countries, people are much healthier and live much longer than before. However, enjoyment of good health is unequally distributed throughout society [3, 4]. Currently, the unhealthiest country in the world (Sierra Leone) has a life expectancy nearly 35 years shorter than the healthiest country in the world (Japan) [5]. Within many countries, inequalities in health are increasing. Australia, one of the wealthier countries in the Organization for Economic Cooperation and Development, has an 11-year of life expectancy gap between one of the most disadvantaged population groups, Aboriginal and Torres Strait Islanders, compared with the non-Indigenous population [4, 6].

Health is not only relates to accessing technical solutions and medical care, but also to the nature of society. The broader facet of evidence shows that the conditions in which individuals are born, live, grow, work and age have a profound effect on health and inequalities in health in childhood, working years, retirement years and older years [7, 8].

The notion that where one lives matters to one's health began in the eighteenth century and reached its peak in the mid-to-late nineteenth century during the public health movements in the United States (US) and Europe [9, 10]. However, it is only recently that interests in the effects of the environment on health and health inequalities has expanded considerably among sociologists, geographers and epidemiologists [8, 10, 11]. One of the most important and persistent observations in the field has been that neighbourhood socioeconomic disadvantage is associated with health above and beyond individual-level socioeconomic characteristics; and that residents of disadvantaged neighbourhoods experience poorer health relative to their more advantaged counterparts. Researchers have subsequently hypothesised that this is because more socioeconomically disadvantaged neighbourhoods have less health-promoting resources, such as services and facilities, social support and job opportunities that enhance the health and wellbeing of residents [12].

1.1.2 Ageing population

As the literature expanded, researchers in the field of gerontology have begun to show interest in the effect of neighbourhoods on health. Gerontologists have suggested that the relationship between the neighbourhood environment and ageing is of particular significance for various reasons. First, older adults have a longer exposure to their neighbourhood environment compared with younger adults [13]. Second, the changes in physical and cognitive capacity associated with ageing may reduce older adults' ability to overcome environmental barriers compared with younger adults [14]. Third, while younger adults may be exposed to multiple contexts (e.g., school, workplace and recreation settings), older adults often experience their neighbourhood environment as the most salient environmental context because of retirement [8]. As the spatial network of resource use diminishes with age, the resources available within the immediate community become increasingly important. Finally, as a result of the ageing process, older adults often experienced shrinkage of social circles due to the passing of their spouse and friends, and the relocation of children, and hence older adults rely more heavily on the local community within neighbourhoods [8].

Population ageing is a triumph of humanity, but also a challenge to society. It is well-recognised that the global population is ageing [15]. By 2021, an estimated 18% of the world's population will be aged 65 years or older, and about four in every 10 households will have at least one elderly person [16]. In Australia, it is projected that the population's age composition of the population will change substantially over the next few decades, due to greater longevity and decreasing birth rates [17]. A recent report from the Australian Government [17] has highlighted that the triangular pyramid shape of the population in 1950 will gradually be replaced with a more cylinder-like structure over the next 50 to 100 years, approaching a highly aged society (Figure 1.1). Growth rates for the oldest segments of the population will increase over the coming years as the 'baby boomer' generation (born between 1946 and 1965) enters old age. The number of people in Australia aged 65 years and older is projected to increase from around one in seven in 2012 to one in four by 2060 [18].

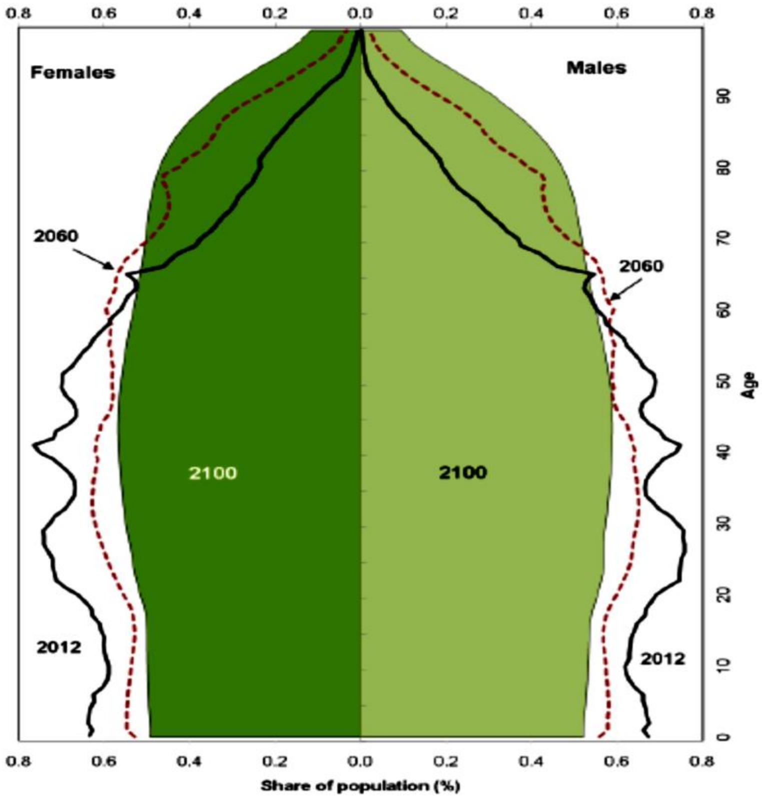

Figure 1.1: The shifting population age structure from 2012 to 2100 in Australia. Adapted from The Productivity Commission, An Ageing Australia: Preparing for the Future [17]

Changes to the population's age profile are likely to have profound implications for the societies in which we live in. The ageing population is often assumed to be a burden to society because of pervasive misconceptions or assumptions that older people are dependent, frail, and make extensive demands on the healthcare system [19]. These stereotypes are outdated and if not careful, could lead to ineffective and rigid public health policy on ageing. Older people contribute to society in numerous ways, and their additional life expectancy might produce new opportunities to transform the way we live. A report from the World Health Organization [19] has advocated that the view of longevity as an extension of retirement is a rigid way to frame a person's life course, and the anticipation of living longer might allow people to do things differently from previous generations. For example, people can spend more time raising children and begin a career at the age of 40, or perhaps choose to retire at 35 and re-enter the workforce at 60. However, the extent of these opportunities will heavily rely on one key characteristic: health.

The ageing process is often characterised by a loss of adaptive response to life challenges and increasing vulnerability to age-related chronic diseases [20]. A decline in all major physiologic systems (e.g., metabolic, respiratory, cardiovascular and neuromuscular) contributes to frailty, fatigue and decelerating of movement, which are all hallmarks of ageing [21-23]. It is estimated that, on average, 50% of muscle mass is lost in the ageing process [24].

1.1.3 Diversity of physical function associated with ageing

Physical function is a measure of one's 'ability to perform various activities that require physical capacity, ranging from activities of daily living (e.g., housework, shopping, walking and climbing stairs) to more vigorous activities that require an increasing degree of mobility, strength and endurance' [25]. Physical function is therefore important, as it provides a substrate for many of the activities considered essential for independent living [26].

Determinants of physical function

Over the past decades, systematic reviews [26, 27], randomised controlled trial [28] and empirical studies [29-36] have identified various individual-level determinants of physical function. These factors are presented in Figure 1.2. Among them, physical activity, self-rated health and smoking are some of the strongest predictors of physical function decline, while the rest have associations with physical function [27]. Age has been commonly identified as a key factor of physical function decline [37, 38]; however, a recent review has suggested that physical function is only loosely associated with chronological age [39]. Pollock et al. [39] have found that the relationship between physical function and healthy ageing is complex, highly individualistic and modified by physical activity levels. The authors have emphasised that physical activity must be taken into account in all ageing studies, as it is one of the strongest predictors of physical function.

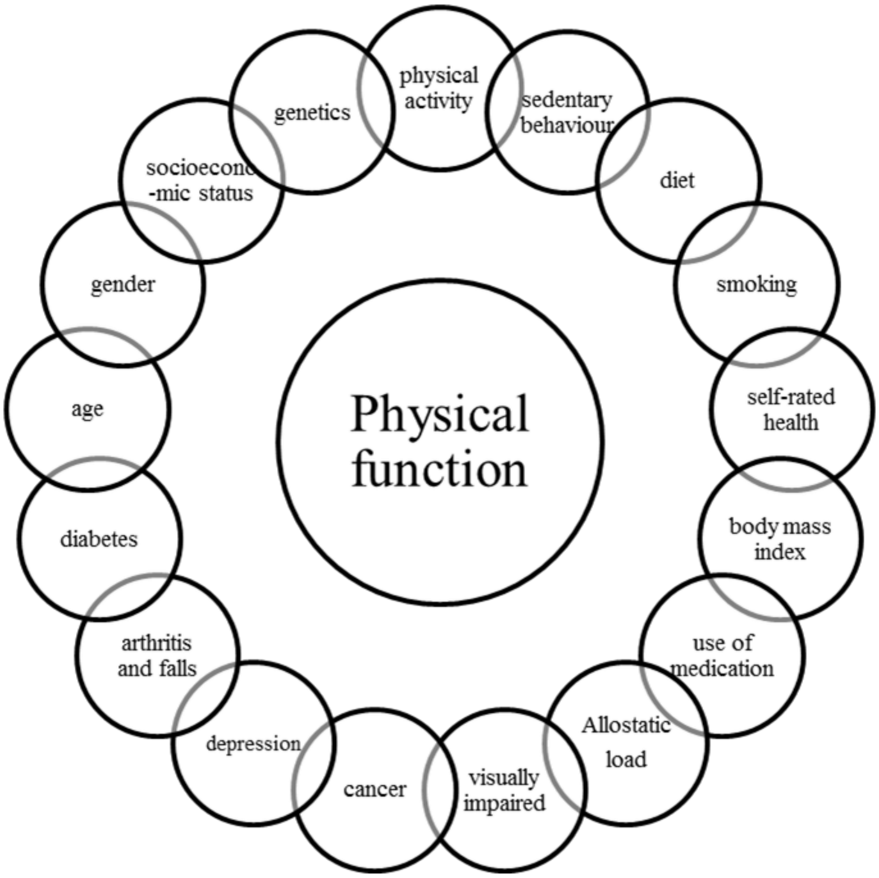

Figure 1.2: Individual-level determinants of physical function

Physical function over the life course

The World Health Organization [19] has presented a useful heuristic of physical function over the life course (Figure 1.3) sourced from the Australian Longitudinal Study on Women's Health (ALSWH) [40]. The figure shows that physical function varies across the life course: it peaks in early adulthood and begins to decline in mid-to-older life. It is important to note that the trajectories of decline are not entirely determined by chronological age, and the trends differ markedly between individuals. For example, some people may become disabled by an unexpected accident at a younger age; or some might die suddenly from an accident while still in a period of good physical function. Figure 1.3 also highlights that the range of physical functioning is far greater among the older than younger age groups (indicated by the top and bottom dark-blue lines). For example, some 70-year-olds will have similar levels of physical capacity to some 20-year-olds. This diversity is a hallmark of older age. On the other hand, Figure 1.3 also demonstrated strong income effects on physical function: individuals reported 'impossible to manage on current income' (indicated by yellow-lines) have poorer physical function scores than those who reported 'easy to manage on current income' (indicated by red-lines) across the life course. Given the large diversity of functional capacity among the ageing population, it is hypothesised that changes in physical function result not only from individual-level factors (e.g., genetics, diet, exercise), but also from the social and physical environment in which people live. One way of explaining this interaction is through the person-environment fit framework proposed by Verbrugge and Jette [41]. This framework reflects the reciprocal and dynamic relationship between individuals and their environments. When the fit between an individual's intrinsic capacity (a combination of all the physical and mental capabilities of a person) and their environment is good, individuals will enjoy the maximum opportunities to maintain and build their functional capacity. However, being exposed to the same environment may have different effects for different individuals, depending on their characteristics. For example, a man may feel safer in a high-crime environment whereas a woman may not [42]. This can result in inequities in physical function.

Therefore, the challenge is to understand and identify the factors that differentiate the top and bottom dark-blue lines shown in Figure 1.3: what factors predict functional decline in mid-life and what factors predict the maintenance of good physical function in later life: this thesis focuses on the latter of these two issues.

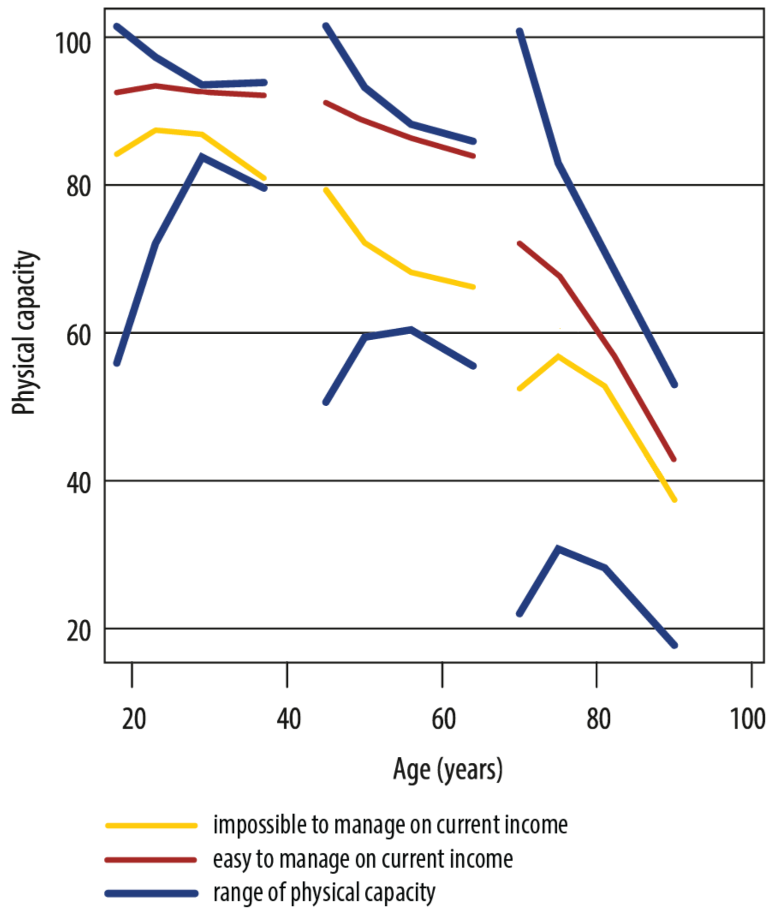

Figure 1.3: Physical capacity across the life cross stratified by ability to manage on current income (adapted from World Health Organization [19])

1.1.4 Neighbourhoods, ageing and diversity of physical function

Bringing together the concepts that (i) the neighbourhood socioeconomic condition matters to health, especially the health of older adults; (ii) the shift in the population's ageing profile; (iii) and the individual- and group-level heterogeneity of physical function in the ageing population, these concepts formed the fundamental basis of this thesis—to understand the contribution of the neighbourhood environment to physical function among middle-aged to older adults. The findings of this study will be both timely and relevant to the public health concerns for current and future generations of ageing Australians.

According to Puska et al. [43], changes at both the environment- and individual-level can offer a complementary approach to disease prevention. The neighbourhood environment can either facilitate healthier behaviour, or act as a barrier to such behaviour. Once these barriers and facilitators are identified, modifications to the neighbourhood environment can be made, which in turn, improve health behaviour. This relationship is illustrated in Figure 1.4, which depicts a person pushing a ball up a hill. The ball represents individual behaviour (e.g., physical activity) and the hill represents environmental barriers (e.g., high crime rate, lack of access to services and amenities), and the more barriers represent the steeper gradient on the hill. When the environmental barrier is 'steep', it makes the pushing of the ball by the individual more challenging. Once the gradient of the hill is modified (e.g., reduced crime, increased access to services and amenities), the pushing of the ball becomes easier.

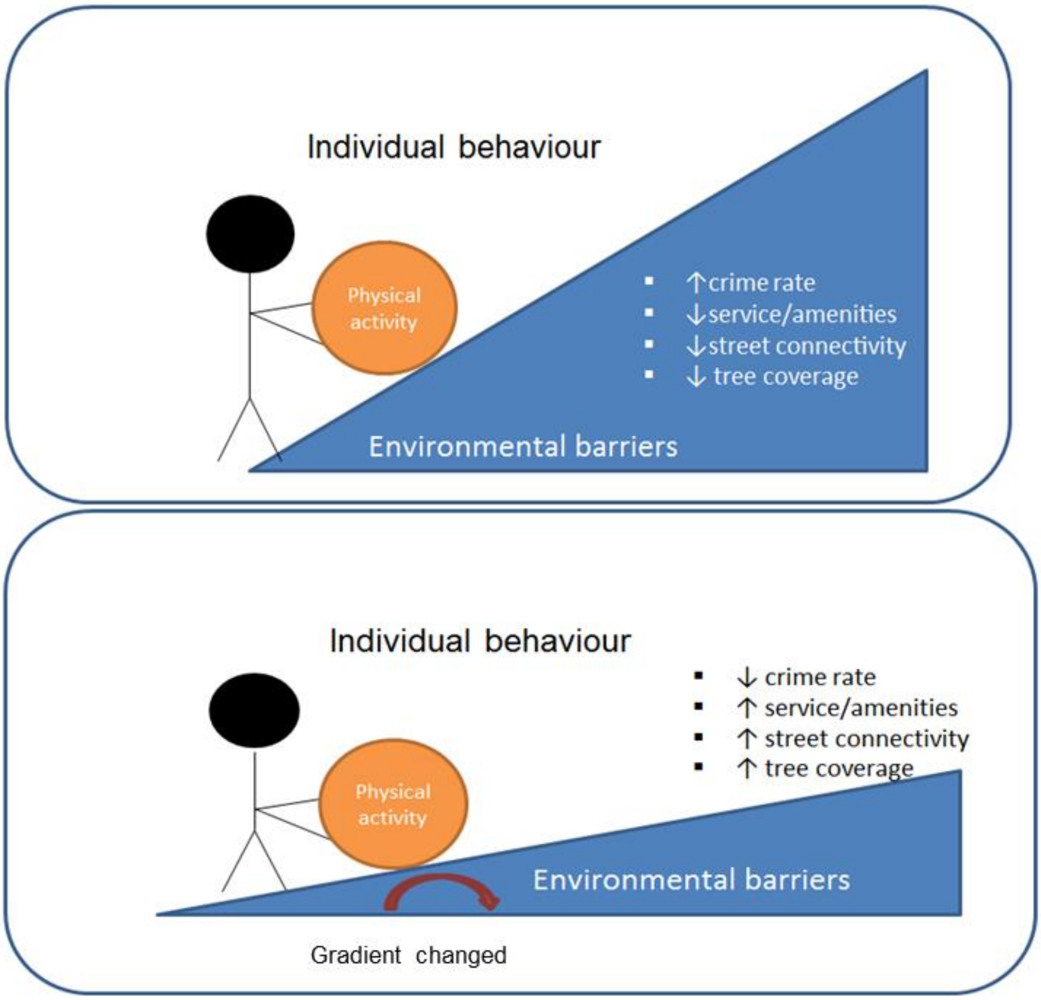

Figure 1.4: Complementary approach to disease prevention (adapted from Puska et al. [43])

Even though a number of studies have examined either individual- or environmental-level influences on physical function among middle-aged to older adults, no known research to date has examined how individual- and neighbourhood-level factors are simultaneously associated with physical function among middle-aged to older adults. To maximise the health and functioning of this growing segment of the ageing population, it is important to identify and address the synergistic effects of both individual- and environmental-level factors on physical function.

A better conceptualisation of the fundamental roles played by the neighbourhood environment and individual behaviour may help to explain why some people experience poorer physical function than others.

1.2 Overarching aims

The primary aim of this PhD project is to examine the contribution of the neighbourhood environment and physical activity to the relationship between neighbourhood socioeconomic disadvantage and physical function in middle-aged to older men and women.

1.3 Study delimitations

This thesis focuses solely on the relationship between the neighbourhood environment, and physical function among middle-aged to older adults. Other environmental settings, such as the workplace and school, are not examined, as they represent a separate research domain targeting different age groups. Acknowledging that multiple individual-level factors are associated with physical function (see Figure 1.2), this thesis focuses on physical activity, as this has been identified as one of the strongest predictors of physical function and is a behaviour often undertaken in the local neighbourhood and hence could be an explanatory factor in terms of advancing our understanding of neighbourhood disadvantage and physical function.

1.4 Structure of the thesis

This thesis comprises seven chapters. Following the introductory chapter, Chapter 2 reviews the literature relating to the neighbourhood environment, physical activity and physical function. Chapter 3 offers an overview of the thesis methodology.
In accordance with the Australian Catholic University PhD requirement, a PhD may be undertaken by traditional thesis, thesis by publication or thesis by creative project. This PhD is a thesis by publication and is thus presented as a series of three publications, which are currently at various stages of review and publication in peer-refereed journals. These three publications are presented in Chapter 4 through 6, and are not mutually exclusive, but interrelate to tell a coherent story. Each publication was written in the publication format stipulated by the target journal. Nonetheless, the referencing style used is consistent throughout the entire thesis document. Due to the stand-alone nature of each manuscript, an inevitable degree of repetition may occur in their Introduction, Methods and Discussion sections. The final chapter—Chapter 7—provides an overall interpretation and discussion of the findings and conclusion to the thesis.

Tables and figures are presented after reference is made to them within the text. A complete reference list is provided at the end of the thesis. All appendices are located immediately following the references.

CHAPTER 2: LITERATURE REVIEW

The socioeconomic, social and physical environment of neighbourhoods can promote health or put health in jeopardy. Features of socioeconomic, physical and social environments often overlap but together they can create vastly different opportunities to be healthy.

Cubbin et al. [44]

2.1 Introduction

This literature review is split into five thematic sections. The first reviews the relationship between neighbourhoods and health, and then delineates the importance of studying neighbourhoods and health among an ageing population. The second section considers the relationship between neighbourhood disadvantage and health, and the third focuses on the relationship between neighbourhood disadvantage and physical function. The fourth section discusses and hypothesises the factors that might explain the relationship between neighbourhood disadvantage and physical function. The chapter concludes with a conceptual framework that underpins the research conducted in this PhD study.

2.2 Neighbourhood level influences on health

In recent years, studies examining neighbourhoods and health have emerged as a frontier of research in public health. The neighbourhood environment is conceptualised as a dynamic system embedded within geographical borders that provides health-relevant resources and social interactions that shape the meaning of place for residents [10, 45, 46]. In health research, the neighbourhood environment is broadly defined as a geographically bounded place encompassing socioeconomic (e.g., the proportion of low-income families, education, employment status, and household structure), social (e.g., perceived safety, social support and social capital) and physical features (e.g., streets, footpaths, shops, trees).

The recently published Lancet series 'Urban design, transport and health' has called for the creation of cities and neighbourhoods that are people-centred, liveable, equitable, sociable and enjoyable in terms of achieving sustainable health and development [47-49]. It is now widely recognised that the neighbourhood environment has the capacity to shape behaviour and improve health. Researchers in this field agree that maintaining health is a complex process in which environmental and personal lifestyle factors are influential. To understand behaviour and health, multidisciplinary and comprehensive approaches are needed. To meet this need, the Social Ecological Model is often adopted as a starting point to guide research in this field [50].

Figure 2.1: The Social Ecological Model of health

The Social Ecological Model posits that health behaviour is shaped by multiple levels of influence, it provides a wide-ranging framework for understanding complex and dynamic interactions of multiple levels of determinants of health behaviours, including intrapersonal (e.g., knowledge, motivation), interpersonal (e.g., social support, culture), community (e.g., built and social environment) and policy (Figure 2.1). The ultimate goal of this model is to inform the development of comprehensive intervention approaches that systematically target mechanisms of change at several levels of influence [50, 51]. Individual behaviour change is estimated to be maximised when all levels of influence support healthy choices: when healthy choices become the easier option due to the supportive environment and policies within an area, when healthy choices are the ‘norm’ within a community; and when individuals are motivated to make those choices [50].

To date, there have been hundreds of cross-sectional and a number of longitudinal studies linking neighbourhood effects to many health behaviours and outcomes such as depression [52, 53], substance use [54, 55], smoking [56, 57], partner violence [58, 59], cardiovascular disease [60, 61], obesity and inactivity [62-64], poor self-rated health [65-

68] and perinatal outcomes [69-71]. A few systematic reviews have explored the relationship between the neighbourhood environment, behaviours and health. One systematic review examining the neighbourhood environment's influence on health among older adults reported that 30 out of 33 studies found positive associations [72], suggesting that neighbourhood environment matters to the health of older adults. Another review looking at neighbourhood characteristics and physical activity across all ages have found consistent positive relationships between a range of physical neighbourhood characteristics (e.g., land use mix, density, proximity, aesthetic qualities, street connectivity, presence of sidewalks and safety) and walking [73]. More recently, a multi-country study (Belgium, Brazil, Colombia, Czech Republic, Denmark, Hong Kong, Mexico, New Zealand, United Kingdom [UK] and US) examined the association between objectively measured built environment and physical activity and found that public transport density, residential density, intersection density and the number of parks within each participant's buffer were positively and linearly associated with moderate to vigorous physical activity [74]. More importantly, the findings were similar across countries that were diverse in terms of income, culture and climate. Therefore, the systematic principle of environment that supports physical activity is applicable at a global scale.

2.3 Neighbourhood effects on health among an ageing population

Although the study of neighbourhood effects on health has burgeoned in recent years, the majority of studies have not focused on middle-aged to older adults [75]. According to Robert and Li [76], neighbourhood-level determinants are especially accentuated among these age groups for a number of reasons. First, older adults may be more vulnerable to the influence of their neighbourhood environment, as they tend to spend more time in their neighbourhood due to the changing pattern of spatial use compared with younger adults [8]. While younger adults tend to be exposed to many contexts including work, school and recreation, the neighbourhood environment is the most salient context for older adults (especially those who have retired). As a result, the resources available within the immediate environment become increasingly important. Second, older adults may be more sensitive to the impact of negative neighbourhood features due to increased biological and psychological vulnerability associated with age. The Person-Environment Fit model developed by Lawton and Nahemow [77] posits that the accentuated vulnerability associated with ageing may reduce an individual’s competence to overcome physical barriers to service use. Third, as the social network and support of older adults often shrinks following the deaths of their spouse, family members, friends and the relocation of their children, they depend more on community resources [78].

Studies looking at neighbourhood environments and healthy ageing have found that negative built environment features subjectively reported by older adults (e.g., uneven sidewalks, poor transportation networks, inadequate street lights), as well as extreme temperatures, are associated with poorer health outcomes [79-81]. Neighbourhood environments that are reported to be pedestrian friendly—smooth and barrier-free footpaths, and good walkability (indicated by connected streets, high density and more diverse mix of land use), have been found to be positively associated with self-rated health and physical activity among older adults and negatively associated with obesity among the same group [63, 82-86].

In parallel with the growing proportion of the population aged 60 years and above, a rising number of older adults prefer to age in place—that is, to remain in their homes and neighbourhoods as they grow older. Therefore, it is important to understand the dynamic role of the neighbourhood environment on healthy ageing [87-89].

2.4 Neighbourhood socioeconomic disadvantage and health

Since the publication of *The Truly Disadvantaged* by Wilson [90], researchers from the field of sociology, epidemiology and gerontology begun investigating the effects of neighbourhood structure on residents' health and wellbeing. In this area of research, neighbourhood socioeconomic conditions are the most commonly examined structural aspects thought to be important for health status [91, 92]. Neighbourhood socioeconomic conditions, also known as neighbourhood disadvantage or neighbourhood deprivation, is a relative concept characterised by multiple and potentially independent social and physical phenomena that shape behaviour and health [93]. Areas with high levels of socioeconomic disadvantage may be disadvantaged with respect to social organisations, safety, transport networks, retail outlets, food environment and environmental pollution, in ways that influence health independent of the socioeconomic characteristics of the individuals living in such areas [10, 93].

Studies that have examined the relationship between neighbourhood disadvantage and health have shown that residents living in more disadvantaged neighbourhoods experience poorer health-related outcomes, including all-cause mortality [94], self-rated health [95, 96], cardiovascular disease [60, 97, 98] and unhealthy behaviours, including alcohol-related problems [55, 99], smoking [56, 57, 100] and higher levels of physical inactivity [101-104]. These findings suggest that some neighbourhoods may be more supportive for health than others.

Attempts to understand the reasons for neighbourhood socioeconomic inequalities in health have led to debate and discussion among public health researchers about the possible causes [8, 10]. De Koninck and Pampalon [105] have argued that the effect of the neighbourhood environment on health is explained by compositional factors, where people with similar individual-level factors (e.g., education, income, culture) tend to aggregate within a geographical proximity. Conversely, some researchers have argued that the association between neighbourhood and health is explained by contextual factors, where the different characteristics of the environment influence health independent of the contribution of individual characteristics [106]. To understand the role of the neighbourhood environment on health, both compositional and contextual factors must be taken into account, as eliminating either will result in bias [107, 108]. Without information from the individual-level factors, neighbourhood-level factors may operate in part or entirely as proxies for individual characteristics, where partitioning the relative contribution of each level to the relevant health outcome becomes impossible. Without neighbourhood-level measures, the influence of individual characteristics may be misunderstood [91]. To overcome this issue, multilevel analysis, a method that differentiates compositional factors from contextual factors, has in more recent times been used by researchers (see Chapter 3 for a more detailed discussion of this topic).

2.5 Neighbourhood disadvantage and physical function

Over the last few years, researchers examining the relationship between neighbourhood environment and health have begun to examine physical function due to the increasing proportion of older adults in most developed countries. A limitation in physical function, which is the precursor to disability, has been recognised as an important subject, as it is modifiable through proper assessment and environmental intervention [109, 110]. Physical function is important for the maintenance of independence among older adults [38]. Before reviewing studies looking at neighbourhood disadvantage and physical function, it is important to understand the definition and concept of physical function. Physical function can be broadly conceptualised across a hierarchy of increasing complexity, from simple and specific physical movements, such as walking and lifting, to more complex and integrated movements, such as the ability to maintain social and occupational roles [111]. More precisely, physical function is defined as 'the *ability* to carry out various activities that require physical capability, ranging from self-care or basic activities of daily living to more vigorous activities that require increasing mobility, strength and endurance' [112].

Verbrugge and Jette [41] have proposed the Model of Disablement Process (Figure 2.2), which describes the pathway to diminished physical functioning in four temporally sequenced phases: it begins with (1) pathology (onset of disease or injury), leads to (2) impairments (anatomic and structural abnormalities), which in turn lead to (3) function limitations (difficulty in simple physical and mental function), resulting in (4) disability (inability to fulfil social or occupational roles). Researchers often use the term 'functional limitation' and 'disability' interchangeably [41, 113]. Although they are related, they do not share the same definition. To distinguish the difference between functional limitation and disability, Haber [114] has described functional limitation as ‘individual capability without reference to situational requirement’ while disability refers to ‘the expression of a functional limitation in a social context’. To explicate this point, functional limitation and disability measure two different aspects of the same behaviour, not two different behaviours. For example, a test of ‘buttoning a jacket’ can measure a pinching action (functional limitation) or the ability to dress oneself (disability).

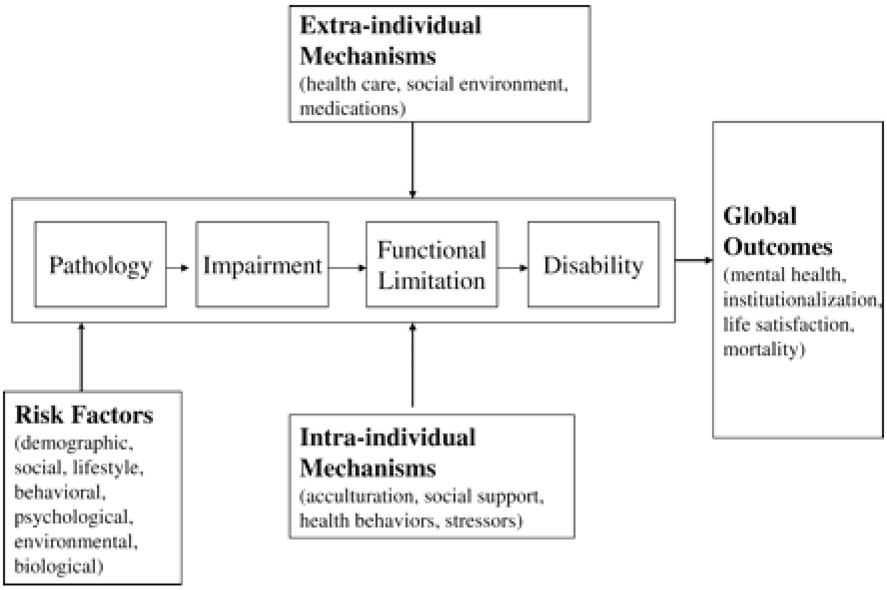

Figure 2.2: The Model of Disablement Process (adapted from Verbrugge and Jette [41])

2.5.1 Evidence to date on the relationship between neighbourhood disadvantage and physical function

Balfour [115] was one of the first researchers to examine the relationship between area-level disadvantage and physical function. In her doctoral thesis, she found substantial variation between census tracts in functional loss among the elderly, using data from the California Bay Area in the US. More recently, seven other studies (four single-level and three multilevel) have examined the relationship between neighbourhood disadvantage and physical function among middle-aged to older adults. Of those studies, three [116-118] were from the UK and four [113, 119-121] were from the US. No known studies examining neighbourhood disadvantage and physical function have been conducted in Australia.

United Kingdom

In a multilevel study examining the effect of area of residence in the UK on physical health among middle-aged to older adults, Wainwright and Surtees [116] found a small but significant association between neighbourhood disadvantage and physical function. Independent of individual-level socioeconomic position (SEP), residents living in more disadvantaged neighbourhoods reported poorer physical function [116].

Using structural equation modelling, Feldman and Steptoe [122] examined pathways through which neighbourhood disadvantage and associated subjective neighbourhood characteristics may be associated with physical function. Their results showed that living in a disadvantaged neighbourhood with greater perceived neighbourhood strain (e.g., noise from traffic and graffiti) was associated with poorer physical function due to greater financial stress, lower perceived control and lower social integration, after adjusting for individual-level SEP.

Similarly, a multilevel study of neighbourhood disadvantage and self-reported mobility disability and objectively measured gait speed among participants aged 60 and older found that those residing in the most disadvantaged neighbourhoods had a higher risk of self-reported mobility difficulties and incident-impaired gait speed, independent of individual-level SEP [118].

United States

There have been mixed findings among the four US studies that have examined the relationship between neighbourhood disadvantage and physical function. Of the four studies, two [113, 119] found a significant association between neighbourhood disadvantage and the prevalence of physical disability and increased risk of lower-body limitations; however, the other two studies [120, 121] found no association. The study by Glymour et al. [121] was the only known study to investigate the causal relationship between neighbourhood disadvantage and the onset of physical function decline using a longitudinal cohort. It was conducted among men and women aged 55–65 at baseline, with a follow-up of 10 years. The results showed that neighbourhood disadvantage did not predict the onset of physical function decline, after adjusting for individual-level covariates.

Summary

Based on the available literature summarised above, although most studies have reported a significant relationship between neighbourhood disadvantage and physical function in the expected direction, it is difficult to draw conclusions about this relationship from these results. First, the measurement of physical function has varied across studies. For example, Beard measured physical function using a single disability item from the Long Form 3 (SF3) questionnaire, while Wainwright and Surtees [116] and Feldman and Steptoe [122] measured physical function using the 10-item Physical Function Scale (PF-10) from the Short-Form (36) Health Survey (SF-36). The different number of items in each measure is likely to capture different dimensions of physical function. Second, there were discrepancies in the methodological approach in these studies, such as sample sizes (ranging from 3442 to 15480), differences in the method of calculating area-level disadvantage, and geographical differences in the sampling of participants (e.g., Wight et al. [120] conducted the study among residents in New York city only, while Freedman et al. [113]'s study was conducted using nationally representative data). Third, despite evidence suggesting gender differences in the association between the neighbourhood environment and health [123], only one study [113] investigated this relationship by gender. Fourth, all previous studies have been conducted in the US and UK, no known Australian study has been conducted. Fifth, no known study has examined whether the same neighbourhood environment affects socioeconomic groups in different or similar ways. For example, an individual with low-income living in a more advantaged neighbourhood might have a better physical function score when compared with an individual with the same income living in a more disadvantaged neighbourhood, due to the benefit of the shared resources in their neighbourhood [12]. Sixth, only three (out of seven) studies examining the relationship between neighbourhood disadvantage and physical function have been conducted using multilevel methods. Therefore, the question remains as to whether neighbourhood socioeconomic environment influences physical function after adjustment for individual-level characteristics. Lastly, studies to date have been mostly descriptive in nature. Our understanding of the mechanisms linking neighbourhood disadvantage and physical function is at a nascent stage. This is evidently an important next step for understanding the relationship between neighbourhood disadvantage and physical function.

2.6 What explains neighbourhood disadvantage, health and physical function?

There are many possible factors that explain the relationship between neighbourhood disadvantage, health and physical function. According to Pickett and Pearl [91],

> "neighbourhood disadvantage might influence health either directly if simply living in a deprived neighbourhood is deleterious to health, or indirectly through mechanisms such as the availability and accessibility of health services, healthy foods, or recreational facilities, pedestrian friendliness, environmental pollution, normative attitude towards health, crime and safety and social support. Measures of neighbourhood socioeconomic status can therefore be viewed as both proxies for unmeasured mechanisms or as actual exposure in their own right, or both".

The following section discusses a number of theoretical perspectives that suggest possible explanations for the association between neighbourhood disadvantage and physical function.

2.6.1 Theoretical perspectives in understanding neighbourhood disadvantage, health and physical function

Various theoretical perspectives that potentially inform our understanding of the relationship between neighbourhood socioeconomic disadvantage and health are discussed below.

In 1993, Macintyre et al. [124] conceptualised five broad factors that explain the relationship between the neighbourhood-level economic context on health: (i) the physical characteristics of the environment shared by all residents; (ii) the accessibility of a healthy or unhealthy environment at home and outside home (work, and leisure); (iii) services and amenities available to support residents in their day-to-day lives, (iv) the neighbourhood's socio-cultural features; and (v) the neighbourhood's perceived reputation. Nine years later, Macintyre et al. [106] further refined their work and proposed that the first three factors can be categorised as infrastructural or material resources, whereas the last two can be categorised as collective social functioning and practices.

Similarly, Robert [125] has suggested that neighbourhood socioeconomic characteristics influence the health of residents through the (i) physical environment (e.g., air and water quality, exposure to toxins), (ii) social services; and (iii) social environments of the communities (e.g., crime and safety).

Northridge et al. [126] have offered an expanded version of Robert [125]'s framework by incorporating health behaviour as part of the pathway between neighbourhood environment and health. They have proposed three pathways through which neighbourhood environment may influence health: the first pathway is through environmental stressors, such as neighbourhood disorder and housing conditions; the second operates through health behaviours such as physical activity; and the third pathway is through opportunities for social interactions within the neighbourhood.

More recently, Kerr et al. [127] have developed a conceptual framework by reviewing literature on the effect of neighbourhood's built and social environments on physical activity and health (Figure 2.3). The solid lines represent a strong relationship between the neighbourhood environment and physical activity types and the dotted lines represent a less consistent or weaker relationship. In the conceptual framework, for example, built environment features, such as walkability, are conceptualised as being strongly associated with transportation walking, whereas social environment features, such as crime and safety, are seen as being strongly associated with recreational walking. The intention and purpose for transportation walking and recreational walking are different. Transportation walking may occur out of necessity (e.g., walking to the train station to travel to work), while recreational walking is a choice (e.g., an evening stroll after meal). Therefore, safety of the neighbourhood may play a secondary role to transportation walking, and the walkability of the neighbourhood may be less relevant to recreational walking. For this reason, researchers have cautioned against combining the two types of physical activity in neighbourhood research as the purpose and direction of transportation and recreational physical activity are different and may produce null associations [128, 129].

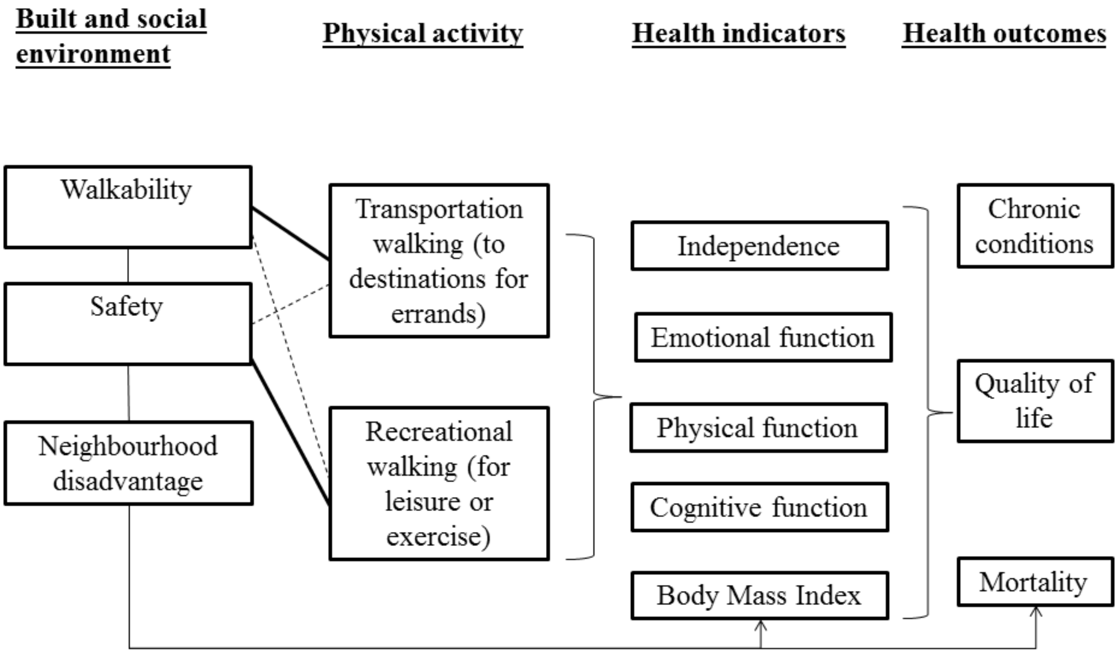

Figure 2.3: Theoretical model of environments and health outcomes among older adults (adapted from Kerr et al. [127])

On the basis of these theoretical frameworks, it is likely that the relationship between neighbourhood disadvantage and physical function can be explained by a wide range of factors. These include air and water quality, availability of health services, housing conditions, and unhealthy behaviours such as alcohol consumption, smoking, poor diet and others. Among these factors, neighbourhood social environment, built environment and their relationships with physical activity are the three most frequently listed factors that may explain the relationship between neighbourhood disadvantage and physical function. Therefore, the next section reviews these three factors in relation to neighbourhood disadvantage and physical function.

2.6.2 Potential pathway between neighbourhood disadvantage, health and physical function: Neighbourhood social environment

Although researchers have not come to an agreement about the definition of the ‘social environment’, elements of the social environment typically include the relationships, groups and social processes that exists within a neighbourhood [130]. Examining the neighbourhood social environment in relation to health has been achieved by using a group of characteristics that encompass the ‘social context’ of the neighbourhood, such as social capital, social cohesion, collective efficacy, social norms and safety from crime [131].

Neighbourhood disadvantage and neighbourhood social environment

The relationship between neighbourhood disadvantage and neighbourhood characteristics has been described as ‘The Spiral of Decay’ [132]. ‘The Spiral of Decay’ suggested that most people do not choose to live in disadvantaged neighbourhoods and, if they must live in one, may not intend to do so for a long period of time. As a result, they may be less likely to maintain their houses and may have a lower sense of ownership and accountability in relation to the physical features available in the neighbourhoods, resulting in structural degradation. These neighbourhoods may be less attractive for commercial investments and crime may be more prevalent in such neighbourhoods [132]. For example, Cerin et al. [133] conducted a mediation study focusing on the role of individual, social and environmental factors in explaining differences in socioeconomic status and walking for transport. The first step was to examine the association between neighbourhood socioeconomic disadvantage and social environment factors. Cerin et al. [133] found that more advantaged neighbourhoods were positively associated with improved social environment features such as sense of community and safety from traffic, but negatively associated with neighbourhood crime.

An earlier study conducted in Glasgow City found that individuals living in more deprived areas were more likely to report fear of crime, discarded needles, incivilities and injury inside and outside home [134]. Similarly, a London study found that those who live in more disadvantaged neighbourhoods were more likely to report negative social features, such as property vandalism, litter and disturbance by neighbours or youth than those living in less disadvantaged neighbourhoods [117].

It is reasonable to assume that neighbourhoods with an aesthetically pleasing environment and lower levels of crime, traffic noise, and property vandalism (typical characteristics of more advantaged neighbourhoods) are conducive to positive feelings of trust that facilitate residents' ownership or sense of belonging to such neighbourhoods.

Neighbourhood social environment and physical function

Studies examining the role of the neighbourhood social environment, such as social cohesion, safety from crime, social capital and health behaviours and outcomes, are emerging. Social cohesion is defined as the willingness of members of a society to cooperate with each other [135], and social capital refers to ‘structures of social organization, such as social network, norm and trust that can improve the efficiency of the social order by facilitating coordinated action’ [131]. It has been documented in the literature that strong social support and connection in a neighbourhood can facilitate or normalise health behaviour [136, 137]. Models such as the Predisposing, Reinforcing and Enabling Constructs in Educational/Environmental Diagnosis and Evaluation framework suggest that in addition to the direct influences of the built environment, its social aspects of the environment may also influence health behaviour in the form of predisposing, enabling and reinforcing factors [138]. For example, an individual’s mental health may be directly affected by living in a physically dilapidated and gloomy environment, while social environment factors may serve to predispose (e.g., neighbours’ encouraging efforts to go out for a walk), enable (e.g., a park close by) or reinforce (e.g., the opportunity to meet up regularly at the park) positive behaviour change [138].

Prior literature has examined the relationship between neighbourhood safety from crime and physical function using self-reported or objective measured neighbourhood safety from crime, and with one study incorporating both. Studies that have used self-reported measures of safety from crime (perceived general neighbourhood safety, perceived neighbourhood problems) [80, 139-142, 143] have shown that these aspects of the social environment are consistently associated with physical function or mobility disability. However, studies that have used objective measures of crime (county/census-level crime report and black segregation) [119, 144] have produced mixed findings on physical function. The only study that included both self-reported and objective measures found that perceived neighbourhood safety was associated with mobility disability only among older persons of retirement age (65–74 years) whose incomes were below the federal poverty line, but objective crime was not associated with mobility disability [145]. It has been established that self-reported measures of crime are a more powerful tool for studying the effect of behaviour, and that self-reported and objective measures crime is weakly associated [146-148]. Despite evidence showing that physical function differs for men and women and the social aspects of neighbourhood environment have larger effects on physical function for women than men [123], only one study [113] stratified by gender and found negligible differences in the relationship between neighbourhood social environment and physical function for men and women.

There are several mechanisms which link fear of crime to poorer physical function. Since one of the behavioural responses to fear of crime is to avoid going places [149], this can reduce the opportunity to develop social ties and participate in social activities that could be beneficial for physical function. In addition, fear of crime may lead to restrictions in outdoor activities [150], such as walking and cycling, leading to an inactive lifestyle and resulting in poorer physical function.

Summary

Despite the inconsistent definition and measurement of neighbourhood social environment features across studies, the findings from such studies have been reasonably consistent, especially in studies examining perceived social environment and physical function among older adults. The potential links between neighbourhood social factors and physical function are complex. To date, there were limited studies that explain the mechanisms through which social environments and physical function may be related. Identifying specific social environment features, as well as the mechanisms that could explain neighbourhood differences in physical function, could inform policy interventions to address social inequalities in health.

2.6.3 Potential pathway between neighbourhood disadvantage, health and physical function: Neighbourhood built environment

As broadly defined in the health literature, the neighbourhood built environment is the physical form of community made by people for people [151] and includes the spatial and functional aspects of urban form such as buildings, transportation systems, open spaces, street connectivity, land use, residential density, sidewalk continuity and the aesthetic quality of the area [10, 152].

Neighbourhood disadvantage and neighbourhood built environment

The relationship between built environment and neighbourhood disadvantage is mixed, and is likely to be dependent on the way in which the built environment is characterised. Consistent evidence has shown that residents living in more disadvantaged neighbourhoods are more likely to be exposed to air [153, 154] and noise pollution [155], worse aesthetics [156] and have more access to fast food restaurants [157, 158], alcohol [99] and tobacco outlets [158] than residents of more advantaged neighbourhoods.

However, evidence supporting an association between neighbourhood disadvantage and walkability is inconsistent. Walkability is broadly defined as a neighbourhood’s capacity to influence residents’ walking behaviour, including walking for recreation (WfR) and walking for transport (WfT) [159]. Extensive public health and transport literature has identified street connectivity, residential density and land use mix as being the three key drivers of walking. A US study [160] found that more disadvantaged neighbourhoods are more likely to be within walking distance of destinations, such as restaurants, shops, churches, more walkable (with more connected street intersections, greater street density and higher density of street segments), but had fewer public open spaces than more advantaged neighbourhoods. Similarly, a study of neighbourhood disadvantage and walking for transport among middle-aged to older adults in Brisbane, Australia found that disadvantaged neighbourhoods were characterised by a more diverse land use mix, well-connected streets, and were residentially denser than advantaged neighbourhoods [161]. A New Zealand study found that residents living in more disadvantaged neighbourhoods had better access to recreational amenities (except for the beach), shopping facilities, educational facilities and health facilities. Conversely, a study conducted in Sydney, Australia found no relationship between neighbourhood disadvantage and walkability [153]. A recently published study conducted in Victoria [162] found that those living in outer Melbourne (more disadvantaged neighbourhoods) were more likely to experience 'transport disadvantage', which is the inability to travel when and where one needs without difficulty, due to the lack of access to public transport infrastructure. Therefore, those living in low-density developments in more disadvantaged neighbourhoods with limited access to public transport infrastructure were potentially doubly disadvantaged, as many did not have access to public transport and some were forced to own a private motor vehicle, which is expensive to maintain.

The mixed evidence in the reviewed literature suggests that built environment characteristics in disadvantaged neighbourhoods may be context specific, as they vary within and between countries. Therefore, researchers investigating the relationship between the built environment and neighbourhood disadvantage should interpret study findings from outside of their jurisdiction with caution.

Neighbourhood built environment and physical function

A number of studies have examined the direct effect of the built environment on physical function among older adults. Three studies have examined the relationship between land use mix and physical function. Clarke and George [110] found that older adults living in neighbourhoods with a more diverse land use mix had greater levels of instrumental activities (e.g., preparing meals, shopping and managing finances); Beard et al. [119] found that more diverse of land use was associated with higher risk of physical disability; and Byles et al. [163] found that more access to services, shops and transport was associated with lower risk of disability.

Studies that have examined the relationship between street connectivity and physical function have produced consistently positive results. Freedman et al. [113] found that residents living in neighbourhoods with poorer street connectivity (indicated by street design) were associated with poorer physical function. Another study among middle-aged African American adults found that between baseline and three years, residents living in areas with the least street connectivity were 3.45 times more likely to develop two or more lower-body functional limitations than those living in neighbourhoods with the greatest street connectivity, after adjusting for other important environmental features, such as the condition of houses, footpaths and the presence of air and noise pollution where the participants lived [164]. A prospective study among women aged 60 and older found that greater street connectivity was associated with a shallower or slower decline in lower-extremity function, but only among women who did walking at baseline [165].

The effects of the micro-level built environment on physical function have also been examined. Two pertinent micro-level features include the quality of footpaths and availability of street lights. Balfour and Kaplan [80], two of the earliest researchers to examine how the neighbourhood environment influences physical function, have shown that residents who reported multiple neighbourhood problems experienced a significantly higher risk of incident-related loss of physical function compared with residents in neighbourhoods with no serious neighbourhood problems, after adjusting for individual demographic and health characteristics. This research also found that poor lighting, excessive noise, traffic congestion and limited access to public transport have the most impact on the overall loss of physical function. A longitudinal study over a 15 year period among American middle-aged to older adults found that residents living in a non-pedestrian-friendly neighbourhood, characterised by cracked or broken curbs, had a 1.5 times higher risk of mobility disability compared with residents living in a pedestrian-friendly neighbourhood, after adjusting for individual-level factors [145].

Summary

In summary, the associations between built environment attributes and physical function were found to be in the expected direction: improvements in neighbourhood built environment features were associated with better physical function. These findings suggest that modifying the built environment that naturally facilitates activities of daily living may delay the rate of decline in physical function among the ageing population.

2.6.4 Potential pathway between neighbourhood disadvantage, health and physical function: Physical activity

Physical activity is defined as ‘any bodily movement produced by skeletal muscles that result in energy expenditure’ [166]. The Department of Health [167] in Australia recommends that adults aged 18–65 engage in at least ‘150 to 300 minutes of moderate intensity physical activity or 75 to 150 minutes of vigorous intensity physical activity, or an equivalent combination of both moderate and vigorous activities per week’ to attain significant health benefits. Physical activity can be undertaken in four different contexts or domains: leisure-time physical activity (LTPA), transport-related physical activity (TRPA), occupational physical activity and domestic related physical activity [168].

Research shows that LTPA and TRPA are the most relevant domains of physical activity in the neighbourhood setting [169]. LTPA refers to recreational physical activity, including activities undertaken for competitive purposes, enjoyment, social interactions or to improve fitness levels that is performed during leisure time [170]. TRPA refers to activities that serve the practical purpose of transporting someone from one place to another for work or to undertake errands. In epidemiological studies, it is important to distinguish LTPA and TRPA as separate outcomes, because each of them is influenced by different characteristics of the neighbourhood environment and the direction of the associations with neighbourhood socioeconomic environment are likely to vary [171]. For example, studies have shown that built environment features are associated with transport-related walking but not recreational walking, whereas neighbourhood safety from crime is associated with recreational walking but to a lesser extent with transport-related walking [127]. As the direction of relationships between neighbourhood-level exposures and physical activity is likely to differ depending on the reason for undertaking physical activity (i.e., for leisure or transport), combining LTPA and TRPA as one physical activity variable may lead to the relationships cancelling each other out, potentially leading to null findings.

As LTPA and TRPA are the most relevant activity domains in neighbourhood studies, the following section only includes studies that have specifically addressed these two domains of physical activity.

Neighbourhood disadvantage and leisure-time physical activity

Research shows that people from more disadvantaged neighbourhoods are less likely to participate in LTPA compared with their counterparts from advantaged neighbourhoods [130]. An earlier US study [172] that examined how the neighbourhood socioeconomic environment influenced change in physical activity found that residents of the most disadvantaged neighbourhoods had a greater decrease in LTPA between 1965 and 1974 compared with those living in the least disadvantaged neighbourhoods. Similarly, a study conducted by Giles-Corti and Donovan [173] found that when compared with residents living in more advantaged neighbourhoods, those living in more disadvantaged neighbourhoods were less likely to use recreational facilities, including tennis courts, the beach, sports and recreational centres, and were less likely to undertake recreational walking on local streets.

Studies have consistently found inverse associations between neighbourhood disadvantage and LTPA. It has been hypothesised that disadvantaged neighbourhoods offer limited opportunities and resources, which may affect residents' behaviour [174]. First, the structure of a disadvantaged neighbourhood may limit physical activity due to fewer amenities, such as bike paths or tennis courts (built environment factors). Second, limited opportunities may then shape residents' attitudes and norms (social factors). For instance, residents may be less likely to exercise if exercise is not seen as a social norm in the neighbourhood.

Neighbourhood disadvantage and transport-related physical activity

Some studies have suggested that cycling and walking for transport do not demonstrate the social inequality gradient that is common for LTPA [175]. In countries with high rates of TRPA, such as Germany, Denmark and the Netherlands, walking and cycling for transport are population-wide activities performed by all age groups, and have subsequently become a social norm [176]. TRPA is effective in promoting physical activity as part of daily life, as it frequently achieves adequate levels of physical activity 'incidentally' at no or low cost across populations [176].

Research shows that people living in the most disadvantaged neighbourhoods are more likely to use public transport or walk to reach destinations, resulting in more TRPA [64]. Similarly, a Dutch study among participants aged 20-69 years who lived in 78 neighbourhoods found that after adjusting for age, sex and individual-level SEP, those living in more disadvantaged neighbourhoods were more likely to walk or cycle for transport than those living in more advantaged neighbourhoods [171].

A longitudinal study in Brisbane among middle-aged to older adults found that the odds of 'never walking' (participants who did not report walking for transport) was significantly lower among residents of disadvantaged neighbourhoods [177]. Similarly, a recent study that used the same Brisbane dataset looking at the association between individual-level SEP, neighbourhood disadvantage and transport mode found that those living in more disadvantaged neighbourhoods were more likely to walk, but not cycle, for transport than their counterparts in more advantaged neighbourhoods [128]. Again, this finding suggests that studies examining TRPA and neighbourhood disadvantage should not combine both walking and cycling into one TRPA measure, as this may produce null associations.

In summary, although the literature indicates that residents of disadvantaged neighbourhoods are less likely to engage in LTPA, they are more likely to achieve physical activity ‘incidentally’ through TRPA. The higher rate of TRPA among residents of more disadvantaged neighbourhoods has been found to be partly attributable to lack of car ownership or living in a neighbourhood built environment with features conducive to TRPA [133, 161]. Identifying the factors that influence walking and cycling for transport within a neighbourhood can potentially narrow neighbourhood socioeconomic inequalities in physical activity.

Neighbourhood social environment and leisure-time physical activity

The influence of the social environment on physical activity and health is now widely recognised in research on health behaviours [130, 178]. Studies have shown that socially cohesive communities tend to experience better health outcomes compared with less cohesive communities [179, 180]. Social cohesion, defined as ‘the extent of connectedness and solidarity among groups in society, combined with the willingness to intervene for the common good, comprise a measure of collective efficacy’ [130]. A related concept, social capital, is the ‘resources available to individuals and to society through social relationships’ [181]. Evidence indicates that greater social participation is associated with an increased likelihood of engaging in higher levels of LTPA [7, 130, 179, 182]. A population study in Canada found that general social support in the form of social contact with family and friends was significantly associated with higher levels of LTPA [179]. A systematic review published by Wendel-Vos et al. [103] found that social support in the neighbourhood setting was associated with leisure walking, bicycling and vigorous physical activity.

Studies examining neighbourhood safety from crime and physical activity have produced mixed results. This is potentially because certain demographics, such as women and older adults, may feel more insecure or vulnerable to crime in their neighbourhoods compared with men and younger adults; and this may have confounded the relationship between perceptions of crime and LTPA. Some studies [85, 183-186] have found an association between higher perceived crime and reduced LTPA, but others have found no association [82, 187].

In summary, studies examining the association between social capital, social cohesion and LTPA have shown consistent positive associations, where higher levels of social capital or more socially cohesive neighbourhoods exhibit higher levels of LTPA. While the association between neighbourhood safety from crime and physical activity have been mixed, one explanation could be due to that ‘global’ or ‘general’ measurements of safety from crime that do not specifically indicate the cause of insecurity [82, 147, 188, 189]. For example, questions such as ‘How safe do you feel walking in your neighbourhood at night’ do not explicitly indicate the cause of insecurity—it could be the rowdy youth, unattended dogs or traffic that causes respondents to feel unsafe [183]. Global or general measurement of safety from crime have been criticised for overrating concern about crime as the question presents respondents with a situation they rarely encounter (e.g., walking at night alone), but nonetheless feel apprehensive about [190]. For that reason, more specific sets of question should be developed to measure safety from crime that can assist in understanding the relationship between this aspect of the social environment and physical activity.

Neighbourhood built environment and transport-related physical activity

Urban design and transportation networks are essential components of the built environment that shape peoples' behaviours [191]. According to Marteau et al. [192], many human behaviours are cued by the built environment design, resulting in actions that are largely unaccompanied by conscious thinking. In recent years, increasing number of studies have examined the influence of walkability on TRPA [193-196]. Walkability is typically indicated by the combination of land use, connected streets and residential density. Land use pattern is characterised by a combination of residences, businesses, and services within an area, with short travel distances between each type of land use. Street connectivity is characterised by the directness and availability of routes from one point to another, with numerous intersections and few cul-de-sacs within a network area. Density refers to the spatial concentration of dwellings, including shops, services and workplaces within a given land area [197]. In general, each of these measures has been independently associated with walking, even though they were highly correlated. The evidence suggests that walkability is more strongly associated with TRPA than LTPA [127]. Studies conducted in the US, Australia, New Zealand and Singapore have found that those living in more walkable neighbourhoods have higher levels of TRPA compared with those living in less walkable neighbourhoods, irrespective of neighbourhood socioeconomic level [161, 198-200]. Further, a study conducted in the US found that the likelihood of walking for non-work purposes increased by 14% for every 25% increase in the level of street connectivity where people lived [201].

Systematic reviews conducted by Saelens and Handy [73], Cerin et al. [202] and Kerr et al. [203] have found strong and consistent relationships between objective and perceived built environment features and TRPA in high- and low-income countries. Saelens and Handy [73] have reviewed a number of studies and found that facilities that support walking and cycling, such as well-connected footpaths and cycling paths, were related to high numbers of people walking to places even when other factors, such as density and land-use mix, were constant. Cerin et al. [202] have reviewed studies of environmental correlates and active travel among older adults and found moderate to strong evidence of positive associations between walking for transport and walkability as well as components of walkability—namely street connectivity, residential density and land use mix. These results were also consistent with their previous work examining the same relationship among younger populations (18–65years), signifying the universal importance of walkability as a determinant for walking for transport across the life course [204]. One of the most intriguing findings of their systematic review was the curvilinear relationship between residential density and TRPA in highly dense areas, such as Hong Kong. Cerin and colleagues [202] found that increasing density in already dense areas might result in decreased walking due to shorter distances between origins and destinations.

Leisure-time physical activity and physical function

Epidemiological studies have demonstrated the causal effect of physical activity on physical function: higher levels of physical activity have been shown to improve physical function [24, 205, 206]. A systematic review by Paterson and Warburton [205] has found that regular aerobic physical activities (at least 150 minutes per week) among middle-aged to older adults conferred a 30-50% reduced risk of physical function decline and disability.

One of the most important findings for physical activity and physical function is that physical activity helps improve functional ability, even among those with existing chronic disease [29].

Walking is one of the most common types of LTPA among older adults. Several studies have demonstrated the benefits of neighbourhood-based walking for health. One study from South Korea [207] found that participants who walked along footpaths within their neighbourhoods for 30–40 minutes had better maximal oxygen capacity than those who did not walk. An intervention study among older adults from 56 neighbourhoods in Oregon, US found that compared with the control neighbourhoods, residents from intervention neighbourhoods who undertook walking-group activity (three times a week over six months) had better physical function than those in the non-walking group [208]. Collectively, these findings indicate that regular LTPA, such as walking may help older adults prolong their capacity for independent living [207, 208].

Transport-related physical activity and physical function

TRPA can substantially contribute to the accumulation of total physical activity in older adults. Unlike LTPA, TRPA is usually incidental and not explicitly undertaken to improve fitness. Therefore, TRPA is less likely to be influenced by the individual-level factors that may affect LTPA, such as self-efficacy, affordability and cultural sensitivity. Studies among older adults from the US, Belgium, and Hong Kong reported that TRPA accounted for 55% (169 minutes) of walking within the neighbourhood, 56% (159 minutes) of total walking and 42% (123 minutes) of total physical activity, respectively [209]. It is well established that higher levels of physical activity are causally related to better physical function [24, 206, 210]. However, most of the studies conducted to date have focused on LTPA or total physical activity rather than TRPA.

In a study exploring the mediating role of the built environment in the association between TRPA and physical function in Belgium, Van Holle et al. [211] found that older adults living in low-walkable neighbourhoods walked less for transport regardless of their functional status, whereas older adults living in high-walkable neighbourhoods walked more for transport—but this only applied to older adults with higher levels of physical function. Importantly, older adults living in low-walkable neighbourhoods walked less, regardless of their physical function. This finding suggests that neighbourhood walkability is not only important to reduce the rate of functional decline through promoting physical activity among younger adults, but also for mobility among older adults.

2.7 A summary of the knowledge gaps on the effect of the neighbourhood environment on physical function

The preceding review of the literature has identified a number of knowledge gaps, and highlighted limitations that merit addressing in future research. In general, very few studies have examined the relationship between neighbourhood disadvantage and physical function. Of those that have examined this relationship, none were conducted in Australia. Given the ageing profile of the Australian population, it is pertinent to identify neighbourhood characteristics that are important for the maintenance of physical function. In addition, it is unclear whether the findings from other countries are generalisable to the Australian context. Despite evidence showing gender differences in response to environmental contexts (e.g., women perceive more risk in their environment than men) as well as physical function profile, only one study stratified the analysis by gender.

One of the most pressing research needs in this area is to understand the mechanism underlying the relationship between neighbourhood disadvantage and physical function. In spite of increasing evidence suggesting that neighbourhood environment matters to physical function, it is still unclear why and how this occurs. Identifying important mechanisms that contribute to the relationship between neighbourhood disadvantage and physical function can offer effective policy interventions to maximise health and function among an ageing population.

2.8 Conceptual framework for the thesis

Derived from the literature reviewed in this chapter, Figure 2.4 illustrates the relationship between neighbourhood environment, physical activity and physical function. To explain this framework broadly, neighbourhood disadvantage is associated with physical function (black arrow), and this association is partly due to neighbourhood social and built characteristics and physical activity (red and green arrow). The relationship between neighbourhood disadvantage and physical function indicated by the black arrow is hypothesised to be linear, whereby residents living in the most disadvantaged neighbourhoods will have poorer physical function.

To unpack the association between neighbourhood disadvantage and physical function, two pathways guided by the reviewed literature were formed. The first pathway (indicated by red arrows) is through neighbourhood social environment and LTPA. It was hypothesised that more disadvantaged neighbourhoods are perceived as less safe from crime, which discourages LTPA within the neighbourhoods leading to poorer physical function. Therefore, neighbourhood social environment and LTPA can explain some of the differences in physical function between advantaged and disadvantaged neighbourhoods.

The second pathway (indicated by green arrows) is through neighbourhood built environment and TRPA. The literature review has revealed mixed evidence for the association between neighbourhood disadvantage and the built environment in that some built features were worse in more disadvantaged neighbourhoods, while other studies conducted in other geographical areas have found the opposite. It was hypothesised that, should more disadvantaged neighbourhoods be characterised by poorer built environment features (i.e., a less diverse land use mix, less street connectivity, and lower dwelling density), then this will not facilitate TRPA among residents of more disadvantaged neighbourhoods, leading to poorer physical function. Conversely should more disadvantaged neighbourhoods be characterised by better built environments (i.e., a more diverse mix of land use, greater street connectivity and higher dwelling density), then this will facilitate TRPA within these neighbourhoods and can help contain or even reduce inequalities in physical function between advantaged and disadvantaged neighbourhoods.

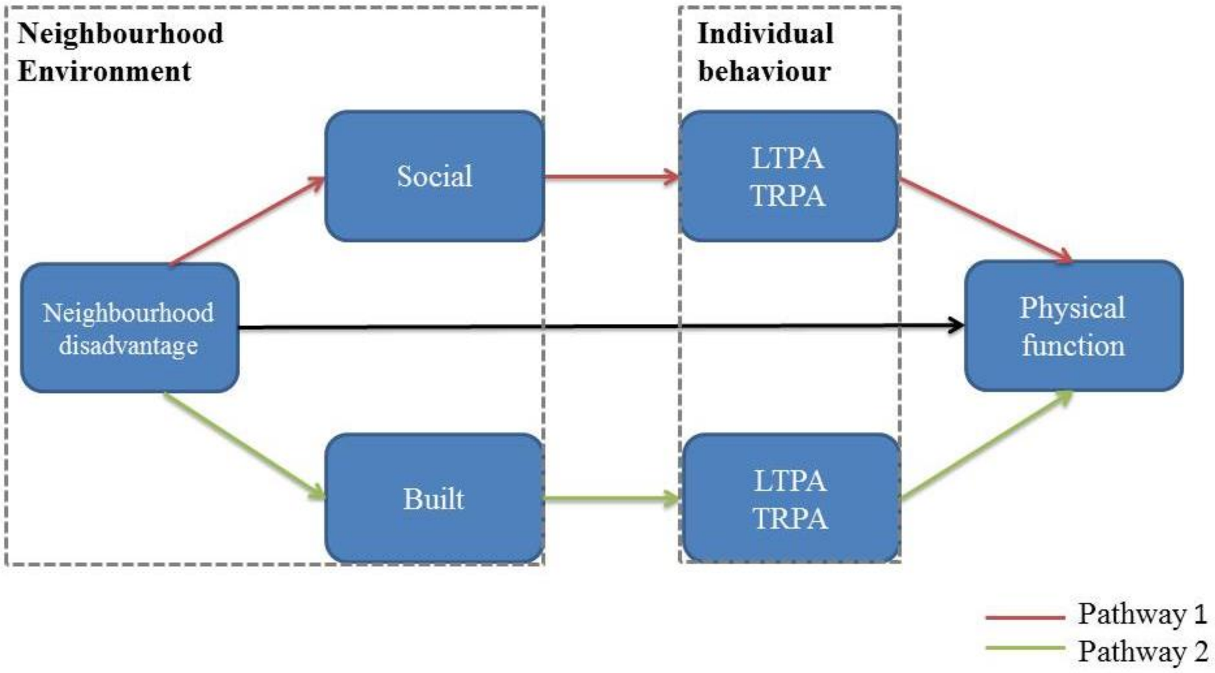

Figure 2.4: Conceptual framework for this PhD

2.8.1 Specific aims

In this thesis, the direct and indirect relationships illustrated in Figure 2.4 are examined as follows.

- Aim 1: to examine the relationship between neighbourhood disadvantage and physical function
- Aim 2: to examine the contribution of the neighbourhood social environment and LTPA to the relationship between neighbourhood disadvantage and physical function (Pathway 1)
- Aim 3: to examine the contribution of the neighbourhood built environment and TRPA to the relationship between neighbourhood disadvantage and physical function (Pathway 2).

2.9 Summary

With the continuing increases in life expectancies in developed countries, an important public health goal is to ensure successful ageing—morbidity compression, maintenance of physical functioning, and active engagement in life. It is well established that the onset of functional decline begins in mid-life, and functional capacity is critical in maintaining mobility, independence and quality of life. Physical inactivity has been shown to be one of the strongest predictors of physical function decline, and a growing body of research is finding evidence of the role of neighbourhood environment on health.

Studies have suggested that neighbourhood disadvantage is associated with physical function. However, the mechanisms underlying this relationship are at a nascent stage. It was hypothesised that neighbourhood disadvantage and physical function may be explained by neighbourhood social attributes and LTPA; and by neighbourhood built attributes and TRPA.

Limited studies to date have explored the mechanisms that explain the relationship between neighbourhood disadvantage and physical function. This type of research is of great public health relevance, because it has the potential to identify a range of new opportunities for neighbourhood design that can improve the functional health of middle-aged to older adults, thus enabling them to live longer in good health.

Guided by the literature reviewed in this chapter, the conceptual framework of the association between neighbourhood disadvantage and physical function, and the two potential pathways that may explain this relationship was hypothesised (Figure 2.4). This framework was used in the development of this PhD study's research methods and analyses, which are discussed in the following chapter.

CHAPTER 3: METHODOLOGY

Knowing is not enough; we must apply. Willing is not enough; we must do.

Goethe et al. [212]

3.1 Introduction

The purpose of this chapter is to describe the quantitative research undertaken to examine the research questions that emerged from the literature review. The chapter also describes aspects of the methods and analyses that could not be covered in the three publications due to word limit. The chapter is divided into two main sections: the first provides information on the secondary data source used in this thesis, including its background and context, scope of the data source, aims and objectives, sampling and data collection; the second provides detailed descriptions of the measures used in this thesis, as well as the analytic plan for analysis, are described.

3.2 Section I: The HABITAT study: the data source used in this thesis

This thesis utilised secondary data from the HABITAT (How Areas in Brisbane Influence HealTh and AcTivity) study. HABITAT is a longitudinal multilevel investigation of physical activity, sedentary behaviour and health among middle-aged men and women, and examines how these outcomes are influenced by psychological, social, environmental, and socio-demographic factors. HABITAT commenced in 2007 (wave 1), and to date, has had data collection waves in 2009 (wave 2), 2011 (wave 3), 2013 (wave 4) and 2016 (wave 5).

3.2.1 Background and context of the HABITAT study

The HABITAT study is conducted in the Brisbane Local Government Area. Brisbane is the capital city of the state of Queensland, and the third largest city in Australia with a population of approximately 2.3 million [213] and a median age of 35 in 2014. The HABITAT study was established because the Australian Government is increasingly confronted by public health challenges that arise from an ageing population, rapid population growth and urbanisation, increased pressure on neighbourhood and city infrastructure and resources, climate change and adverse weather events, rising rates of chronic disease and obesity and the widening of social and economic inequalities in health and related behaviours [214-216]. The HABITAT study intends to address these challenges by identifying multilevel determinants of health to assist policymakers and practitioners in the design and implementation of appropriate interventions. The HABITAT study is funded by the National Health and Medical Research Council (NHMRC) (ID 497236, 339718, 1047453). The aims of the study are (1) to examine changes in physical activity, sedentary behaviour and health (physical and mental) among middle-age men and women (from 2007 to 2017), and (2) to assess the relative contributions of, and interactions between, environmental, social, socio-demographic, and psychological factors, and changes in physical activity, sedentary behaviour and health [217].

The target population for the HABITAT study is set to be among middle-aged men and women because many of these individuals will experience the onset of chronic disease and functional decline accompanied by the ageing process [218]. Middle-aged adults also have high rates of inactivity, overweight and obesity and make above-average use of the health care system [219].

The HABITAT study is underpinned by a social ecological framework [50]. Figure 3.1 illustrates a broad overview of the HABITAT framework.

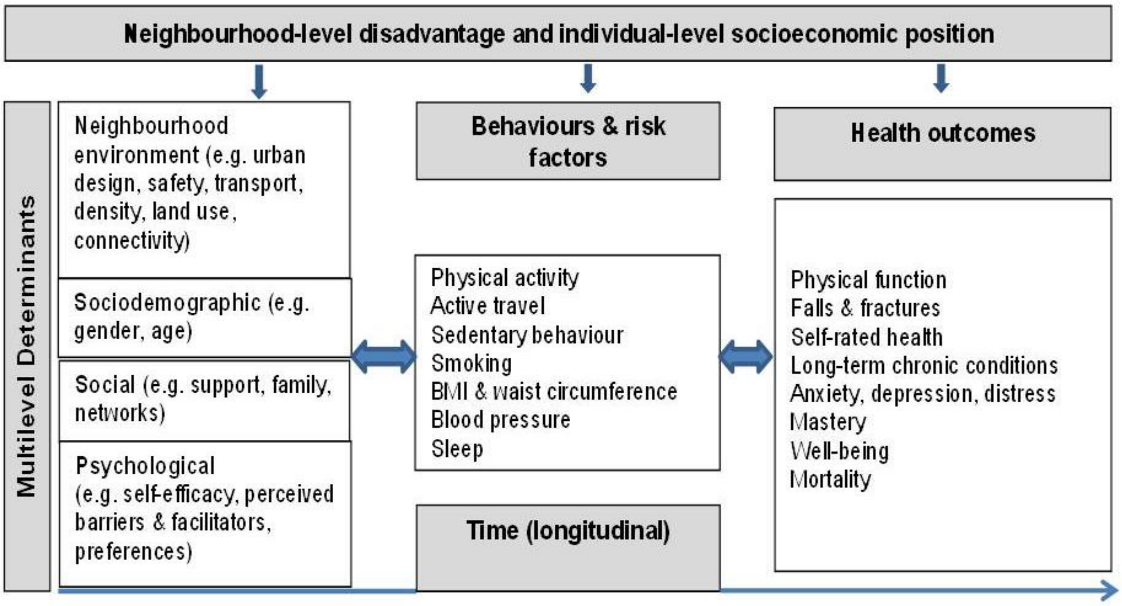

Figure 3.1: An overview of the multilevel relationships being examined in the HABITAT study

As depicted in Figure 3.1, neighbourhood disadvantage and individual-level socioeconomic position (SEP) are conceptualised as influencing various physical and social features of neighbourhoods, health-related behaviours and risk factors, and health outcomes. These factors are depicted as influencing each other independently and interdependently (indicated by double head arrows) over time.

3.2.2 Overview of the HABITAT study design

Table 3.1 offers an overview of the HABITAT study design. The study currently comprises five waves over 10 years (from 2007 to 2017). Data collection has been undertaken biennially except for wave 5 (occurred after a 3-year gap from 2013 to 2016). The clinical sub-study that collected objectively measured data was undertaken for waves 4 and 5. Participants who moved at some point during the study period have also been tracked. Participants who moved throughout the survey years received a special survey that asked them about the reasons for leaving their previous address, and the factors that influenced their decision in choosing their new place of residence. In addition to helping to address selection effects, the 'movers' cohort in the HABITAT study can be used to conduct natural experiments type designs, by investigating how changing one's neighbourhood influences changes in health and related behaviours.

Table 3.1: Overview of the HABITAT study design

Year	Wave	Data collection	
2007	Wave 1: baseline	Mail survey (n = 11,035) Spatial data	
2009	Wave 2	Mail survey (n = 7,866) Spatial data	Movers and stayers
2011	Wave 3	Mail survey (n = 6,900) Spatial data	Movers and stayers
2013	Wave 4	Mail survey (n = 6,520) Spatial data	Movers and stayers
2014/2015		Clinical sub-study	
2016	Wave 5	Mail survey (n = 5,188) Spatial data	Movers and stayers
2016/2017		Clinical sub-study	

3.2.3 Sampling design and selection methods

The study area and participants were selected using a stratified two-stage design, where the study areas were selected first, followed by participants within those selected study areas. The sampling design and selection methods are described in the following sections, more detail is provided in Burton et al. [217].

Stage one: Random sampling of neighbourhood

The smallest administrative unit used by the Australian Bureau of Statistics (ABS) for the collection of census is the Census Collection District (CCD). A CCD was used as the initial area-level sampling unit in the HABITAT study. In 2001, there were 1,680 adjacent CCDs in the Brisbane Local Government Area and containing an average of 220 dwellings per CCD, ranging from 0 to 697 dwellings. To obtain the within-CCD sampling targets, areas containing populations fewer than 50 dwellings were excluded (n = 30), resulting in 1,625 CCDs. Based on the 2001 census data, the excluded CCDs had a higher proportions of early school leavers (51% in the non-sampled CCDs vs. 43% in the sampled CCDs), persons employed in semi- and unskilled occupations (17% vs. 13%), and low-income households (24% vs. 20%). The 1,625 CCDs were first ranked by the Index of Relative Socioeconomic Disadvantage (IRSD) scores, and then divided into deciles (10 groups). Then, 20 CCDs from each decile were randomly selected, totalling 200 areas for study inclusion. The 200 sampled CCDs and the 1,425 non-sampled CCDs had similar proportions of persons employed in semi- and unskilled occupations (14% vs. 13%, respectively), low-income households (19% vs. 20%, respectively) and early school leavers (44% vs. 43%, respectively).

Figure 3.2 presents the geographical scope of HABITAT's sampled areas. Areas marked from warmer (red and orange) to cooler colours (green) represent neighbourhoods that are the least to most disadvantaged, respectively.

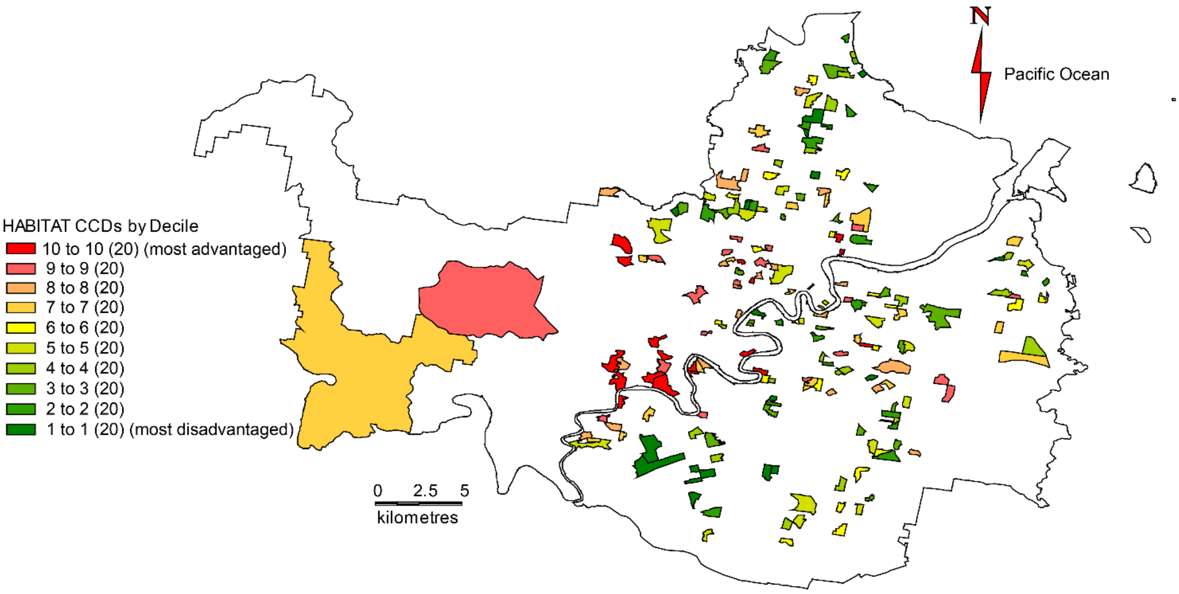

Figure 3.2: HABITAT sampled areas (n = 200) in Brisbane

Stage two: Random selection of individuals within selected neighbourhoods

Identification of households situated in each of the 200 CCDs was made possible through the Australian Electoral Commission (AEC) database. Households with at least one person aged 40–65 years as at March 2007 were selected for sampling. Systematic without replacement probability proportional-to-size sampling was undertaken, with size defined as the number of households per CCD (n = 85) with at least one person aged between 40–65 years. The final stage of the sampling included randomly selecting one individual (of those aged 40–65) from the 17,000 households (85 x 200).

Figure 3.3 presented an overview of the two stage HABITAT sampling procedure.

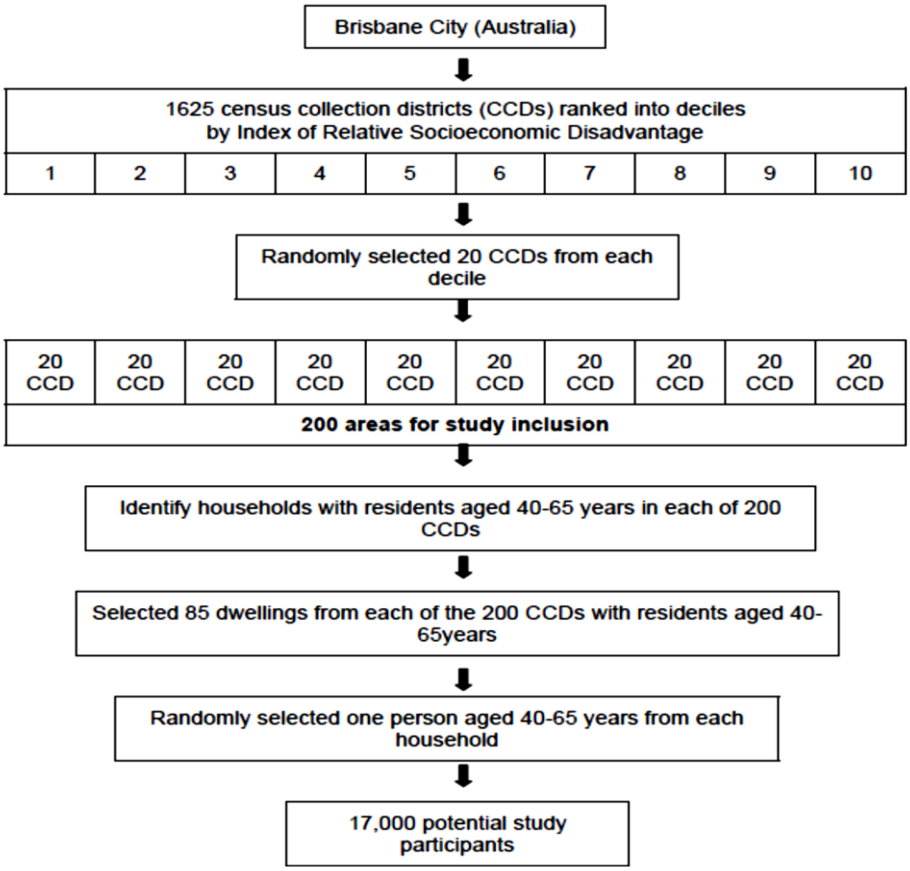

Figure 3.3: Overview of sampling procedure to identify HABITAT study areas and participants. (sourced from Burton et al. [217])

Procedure

The questionnaires were sent during May-July in 2007, 2009, 2011, 2013 and 2016 using the mail survey method developed by Dillman [220]. Dillman's *Tailored Design Method* (TDM) uses social exchange theory to guide the careful integration of specific procedures and techniques. This theory posits that survey recipients are most likely to respond when the perceived reward exceeds the cost of responding. This method suggested a response rate of 50-70% if a series of precisely laid-out steps are closely followed [221].

For the HABITAT baseline survey (2007), newspaper advertisements about the study were published one month prior to the questionnaire distribution. Guided by the TDM, a pre-notice letter was mailed out one week prior to mailing the survey questions. Then, the questionnaires printed in booklet format were posted in May (2007, 2009, 2011, 2013 and 2016), with a personalised cover letter that describes the purpose of the study and the social usefulness of the respondents' involvement, each signed by hand in blue ink, as well as a pre-addressed prepaid reply envelope for return. One week later, a postcard was mailed to the entire sample as a token of appreciation to those who had returned their survey, and to remind those who had not yet done so. Three-and-a-half weeks after the initial mailout, a personalised reminder letter and replacement questionnaires were sent to all non-respondents, and a final reminder letter to non-respondents was sent two weeks after the previous contact attempt. To optimise the retention rate and maintain contact with the HABITAT participants, several strategies were incorporated:

1. A variety of contact details were collected from participants, such as residential address, postal address, telephone numbers (home and mobile) and email address.
2. Newsletters with a brief results summary were included in the non-surveyed years (2008, 2010, 2012 and 2015) to show participants how the data were being used and to re-emphasise the importance of their continued contribution. A change-of-address card was also included in the mailing in case anyone had moved.
3. Participants received a small gratuity (lottery ticket) with each questionnaire (except for the 2016 survey due to insufficient funding).
4. Each questionnaire included a request for participants to provide contact information for someone 'who will always know where you are if you move'.
5. As a token of appreciation, Christmas cards were sent to participants each year. This mailing also included a change-of-address card in case anyone had moved.
6. Participants could access the HABITAT project website (https://iha.acu.edu.au/research/research-projects/habitat-project/); and a Freecall

phone number to contact HABITAT staff for more information or to advise a change of address.

7. In the case of participants whose questionnaires were received as returned to sender, their updated contact details could be found via the electoral roll or Australia Post mail redirection.
8. The National Death Index was checked to identify the decedent status of non-respondents.

The total number of usable surveys returned at each wave was 11,035, 7,866, 6,900, 6,520, and 5,188, respectively. The response rate at baseline was 68.4% (11,035 surveys from 16,127 eligible and contactable respondents); 72.5% in 2009 (7,866/10,837); 67.3% in 2011 (6,900/10,252), 67.1% in 2013 (6,520/9,716) and 57.2% in 2016 (5,188/9,069).

3.2.4 Data collection

There are a mix of study data types in the HABITAT study. The first study type is the main observation study, which collected data using a mail survey method, as well as procuring spatial data from the Brisbane City Council and other organisations (2007, 2009, 2011, 2013 and 2016). The second study type is the clinical sub-study which collects data using self-administered surveys and direct objective measurement of participants (2014/2015 and 2016/2017). This thesis only used data from the main observation study (mail survey and spatial data); therefore, details about the main study data collection will be discussed.

Main study: Data collection from mail survey

At each wave, individual-level data were collected using self-administered mail questionnaires in a booklet form (see Appendix II). Survey items were grouped into sections to assess perceptions of the neighbourhood (e.g., safety, footpaths, traffic, aesthetics, cohesion), proximity to facilities from residence, access to and use of public and private transport, physical activity (e.g., recreational, transport, occupation-related), psychological and social determinants of physical activity, sedentary behaviour, dog ownership, social influences on physical activity, mental health, general health status, chronic disease (e.g., cardiovascular disease, asthma, cancer, diabetes, arthritis), socio-demographic variables, SEP, life events (e.g., retirement, children leaving home, separation from partner, unemployment), falls and fractures, length of residence and reasons for moving to new address (if the participant had recently moved).

Items related to neighbourhood perceptions and proximity to services were adapted from the Abbreviated Neighbourhood Environment Walkability Scale (ANEWS) questionnaire (http://www.ipenproject.org/docs/ANEWS.doc.) [222]. Physical activity items were used from the Active Australia Survey [223]. The physical activity items have acceptable levels of reliability and validity among community-dwelling older adults [224]. Recreational activities were identified from the Exercise, Recreation, and Sport Survey [225]. Sedentary behaviour items were adapted from those used in the ALSWH and have been shown to be more reliable and valid for weekdays than weekends, and more valid for the domains of watching television, being at work and computer use at home than for other domains [226].

The majority of survey items used a five- or six-point Likert scale response format, with response ranging from ‘strongly disagree’ to ‘strongly agree’. Some items required participants to tick the most relevant box, for example, response options ranged from ‘excellent’ to ‘poor’ or ‘very weak’ to ‘very strong’ or from ‘dissatisfied’ to ‘satisfied’. Items assessing the time taken to either drive or to identify destinations used response options of 1–5 minutes, 6–10 minutes, 11–20 minutes, 21–30 minutes, greater than 30 minutes, and don’t know. Some items were open-ended questions that required participants to write their answers. Other items, such as health conditions, professional advice, smoking status, dog ownership, pregnancy and motor vehicle ownership, required a yes/no response.

Main study: Data procured from other sources

A MapInfo geographic information systems (GIS) database was used to collate spatial data. Data were provided by National Resources and Water, Energex (electricity supplier), the Bureau of Meteorology, Queensland Transport, the local council (Brisbane City Council), online databases (such as the telephone book) and environmental audits. These data were used to derive objective measures of street connectivity (three- and four-way intersections); residential and population density; hilliness; land use mix; street lighting; public open space; bike paths; Brisbane City Council bike hire stations; public transport nodes (bus, train and ferry); 2011 flood levels and distance by road from each respondent’s home to the closest shop, park and public transport. A detailed GIS database was compiled for each of the 200 neighbourhoods that included an extensive array of objectively measured features. The GIS database was updated using the same environmental features in every wave as in 2007. Having near identical neighbourhood- and individual-level data across several time points facilitates an examination of how change at both levels affects change in psychosocial factors, behaviours, and health outcomes.

3.3 Section II: Measures used in this PhD

Details of the methods for each specific study are provided in the manuscript. The purpose of this section is to describe the expanded methodological information for each measure included in the studies that could not be included in the publications. Prior to describing the measures, the first sub-section offers an overview of the study design for this thesis.

3.3.1 Overview of study design

Although the HABITAT study is a longitudinal study that measures physical function subjectively and objectively, only the self-reported physical function measure from wave 4 was used for this program of research. This is because, at the time the thesis commenced (March 2014), physical function items was only available in that wave, and the objective measures of physical function from the clinical sub-study had yet to commence. Therefore, only cross-sectional analyses were possible for all studies in this thesis.

3.3.2 Main exposure: Neighbourhood disadvantage

The IRSD score is one of the four indices created by the ABS from social and economic information obtained from each census from 1986 to 2011[227]. Using the ABS IRSD score, every residential point (parcel of land) in Brisbane was assigned a socioeconomic score [228]. The IRSD score summarises a variety of information about the socioeconomic conditions of geographic areas. Generally, greater disadvantage is indicated by a lower IRSD score, and lesser disadvantaged is indicated by a higher IRSD score. For example, an area could have a low score if many people within the area have low education attainment, do not have internet connection at home or are unemployed.

Table 3.2 presents the variables included in the IRSD index. Each variable has a loading indicating its correlation with the IRSD index. Variables with a negative loading indicate disadvantage. The percentage of low-income households is the strongest indicator of disadvantage.

Table 3.2: Variables included in the Index of Relative Socioeconomic Disadvantage in 2011

Variable included in the IRSD index	Loading
% of people who do not speak English well	-0.34
% of people aged 15 years and over who have no educational attainment	-0.44
% of employed people classified as low skill Community and Personal Service workers	-0.50
% of employed people classified as Machinery Operators and Drivers	-0.52
% of occupied private dwellings requiring one or more extra bedrooms	-0.52
% of people aged 15 years and over who are separated or divorced	-0.54
% of occupied private dwellings with no cars	-0.56
% of people under the age of 70 who have a long-term health condition or disability and need assistance with core activities	-0.66
% of one parent families with dependent offspring only	-0.71
% of occupied private dwellings paying rent less than $166 per week (excluding $0 per week)	-0.73
% of people (in the labour force) who are unemployed	-0.74
% of people aged 15 years and over whose highest level of education is Year 11 or lower	-0.75
% of employed people classified as Labourers	-0.75
% of occupied private dwellings with no internet connection	-0.81
% of families with children under 15 years of age who live with jobless parents	-0.85
% of people with stated household equivalised income between $1 and $20,799 per year	-0.90

Source: Australian Bureau of Statistics [228]

The ABS collects IRSD data at the time of each census. For HABITAT baseline sampling, the 2001 CCD boundaries in Brisbane were used. The CCD was the geographic area used by the ABS and in HABITAT for the measurement of environmental data. However, for the 2011 census, the ABS made substantial changes to the standards and geographical classifications from the Australian Standard Geographical Classification to the Australian Statistical Geography Standard, which resulted in changes of geographical units and boundaries used for measuring spatial data (the unit of analysis changed from

CCD to Statistical Area Level 1 [SA1]). As a result, comparing the IRSD scores over time may lead to deceptive or false results. To address this issue, the HABITAT data manager (Mr Paul McElwee) derived a linear regression trend for each time point from the IRSD scores from 1986–2011. For each period of interest, the calculated IRSD value from the linear trend was generated, and weighted according to its proximity to the nearest ABS census. The average of the calculated IRSDs for each point was derived for the HABITAT neighbourhoods in which they occurred. The derived HABITAT neighbourhood IRSD scores were then quantised as percentiles, relative to all of Brisbane. The 200 HABITAT neighbourhoods were then grouped into quintiles based on their IRSD scores, with Q1 denoting the 20% (n = 40) least disadvantaged areas relative to the whole of Brisbane, and Q5 denoting the most disadvantaged 20% (n = 40). In wave 4, there were larger proportions of participants residing in the least disadvantaged neighbourhoods.

The IRSD index captures more than just the aggregated properties of individuals living in a given area; they are also considered to capture an area's collective (social-cultural) and contextual (physical environment) properties [44]. This has been demonstrated through studies examining area-level disadvantage and health that persists even after adjusting for individual-level socioeconomic status, suggesting that individual socioeconomic status does not entirely explain the relationship [60, 229]. However, the IRSD has its limitations. The concept of the IRSD is considered poorly defined, as the wide range of information that comprises the IRSD index is broad, and each of the variables included in the index may not necessarily share the same level of association with health [230]. As a result, the use of the IRSD made it difficult to identify which aspects of socioeconomic disadvantage should be focused upon when proposing interventions [230]. Additionally, census-based areas were defined for administrative purposes, which may not adequately capture the true neighbourhood characteristics [231].

3.3.3 Main outcome: Physical function

These data were collected using the PF-10, a component of the SF-36 [232]. The SF-36 Health Survey is a self-report, 36-item survey measuring health-related quality of life. The PF-10 has been extensively validated among community dwelling adults using convergent validity calculated by Pearson’s correlations using three performance-based measures: single-limb stance as an indicator of balance ($r = 0.42$), Time Up and Go test as a measure of mobility ($r = –0.70$) and gait speed as an indicator of overall functional capacity ($r = 0.75$) [25]. The scale was designed to minimise respondent burden, yet remains comprehensive so that it samples a core set of questions for those with and without acute or chronic conditions [25]. A previous review found a three point difference in physical function score measured by SF-36 to be clinically meaningful for effective intervention [233]. Table 3.3 gives an example of the PF-10 question.

Table 3.3: Physical Function-10 items

The following questions are about activities that you might do during a typical day. Does your health now limit you in these activities? If so, how much?				
Please tick one box for each item		Yes, limited a lot	Yes, limited a little	No, not limited at all
PF1	Vigorous activities such as running, lifting heavy objects, participating in strenuous sports			
PF2	Moderate activities such as moving a table, pushing a vacuum cleaner, bowling or playing golf			
PF3	Lifting or carrying groceries			
PF4	Climbing several flights of stairs			
PF5	Climbing one flight of stairs			
PF6	Bending, kneeling or stooping			
PF7	Walking more than one kilometre			
PF8	Walking half a kilometre			
PF9	Walking 100 meters			
PF10	Bathing or dressing yourself			

Recoding of missing physical function items

The ALSWH developed a method to re-code missing items in the PF-10 subscales [234]. There were three sets of related items within the PF-10 sub-scale that establish the level of function for specific activities: (i) overall activity level (PF1-3), (ii) climbing (PF4-5) and (iii) walking (PF7-9). Where a higher level of functioning in each set is ‘No, not limited at all’, but the item(s) for a lower level of related function is (are) missing, the lower level of functioning is re-coded to ‘No, not limited at all’. Conversely, where a lower level of functioning is ‘Yes, limited a lot’, and the item for a higher level of the related function is missing, the higher level of functioning is re-coded to ‘Yes, limited a lot’. To illustrate this further, Table 3.4 shows an example of survey response codes for walking (PF1-3) and recoding approaches.

Table 3.4: Example for recoding an item in the Physical Function-10 sub-scale

Overall activity			
PF 1: vigorous activity	**PF 2: moderate activity**	**PF 3: lifting and carrying groceries**	**Recode**
Yes, not limited at all	Missing		Moderate activity recoded as 'Yes, not limited at all'
Missing	Yes, limited a lot		Vigorous activity recoded as 'Yes, limited a lot'
Missing		Yes, limited a lot	Vigorous activity recoded as 'Yes, limited a lot'

Once missing items were re-coded, raw scores of physical function were calculated as the sum of scale items and transformed to a 0–100 scale according to Equation (1):

Equation (1):

$$Transformed\ physical\ function\ score = \frac{Raw\ score - Minimum\ raw\ score}{Possible\ raw\ score\ range} \times 100$$

The transformed physical function measure was positively scored so that higher scores represented better physical function. Figure 3.4 presents the percentage distribution of each item group by specific activities, as well as the transformed physical function scores for men and women. The Pearson's chi-square test revealed that men and women were significantly different in their reporting of items 1 to 8 ($p < 0.001$), but not items 9 and 10.

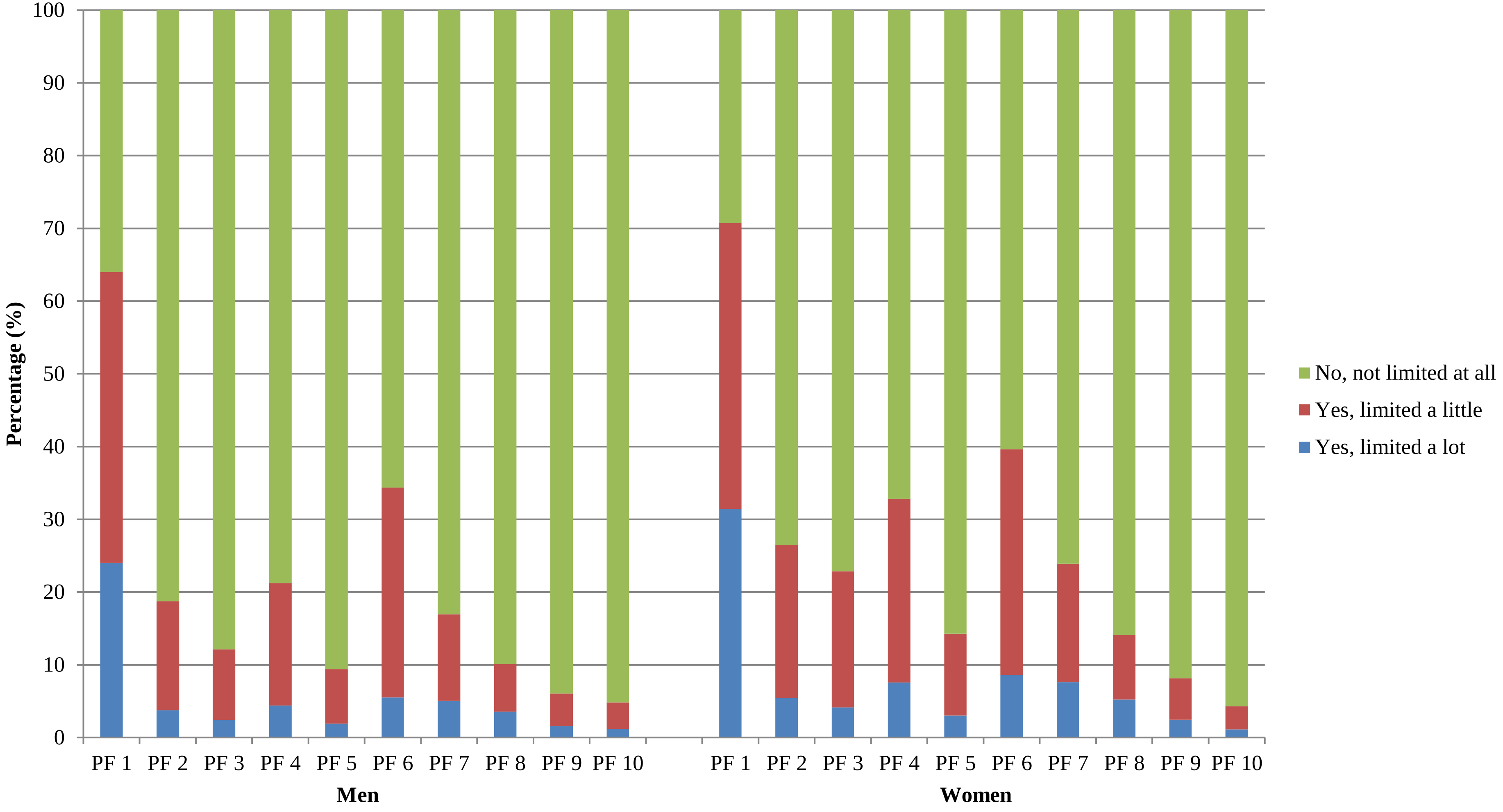

Figure 3.4: Percentage distribution of each item in the Physical Function-10 Scale by gender

Figure 3.5 shows the association between age and physical function. Generally, those in the older age group had lower physical function. Women appeared to have a lower physical function scores than men, and this difference became more apparent at the age of 61 and older.

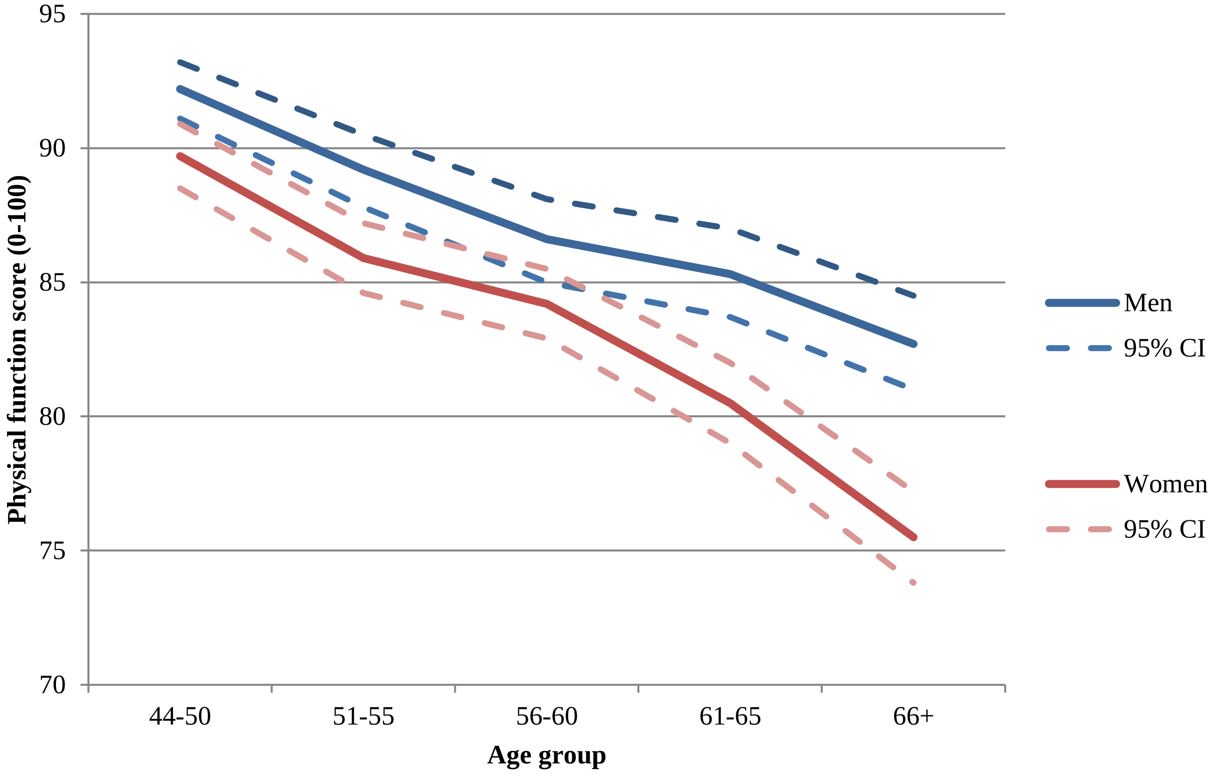

Figure 3.5: Mean physical function score by age group and gender

3.3.4 Social environment measure: Perceptions of safety from crime

Neighbourhood-level perception of safety from crime (NPSC) was the social environment measure used in this thesis. This variable was used to address Aim 2 of the thesis.

Participants were presented with six statements and asked to respond using a five-item Likert scale, with items ranging from ‘strongly disagree’ to ‘strongly agree’ (Table 3.5). The statements were adapted for the Australian population from the ANEWS questionnaire, which has been shown to have acceptable validity and reliability for measuring perceived neighbourhood walkability [222, 235].

Principal Component Analysis (PCA) with Varimax rotation revealed that the six items loaded on one ‘perceptions of safety from crime’ factor, with a Cronbach’s alpha of 0.82 for men and 0.80 for women.

Table 3.5: Statements about safety from crime in respondents’ suburb

The following statements are about crime and safety in your suburb. How much do you agree or disagree with each statement?					
Please tick the box that best applies to your suburb	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
There is a lot of crime in my suburb					
Children are safe walking around the suburb during the day					
The level of crime in my suburb makes it unsafe to walk on the streets at night					
There are rowdy youth on the streets or hanging around in parks in my suburb					
The level of crime in my suburb makes it unsafe to walk on the street during the day					
In my suburb, I would feel safe walking home from bus stop or train at night					

Figure 3.6 presents the percentage distribution of each item by gender. The Pearson’s chi-square test showed that men and women were significantly different in their responses to each statement about safety from crime in their suburb of residence ($p < 0.001$).

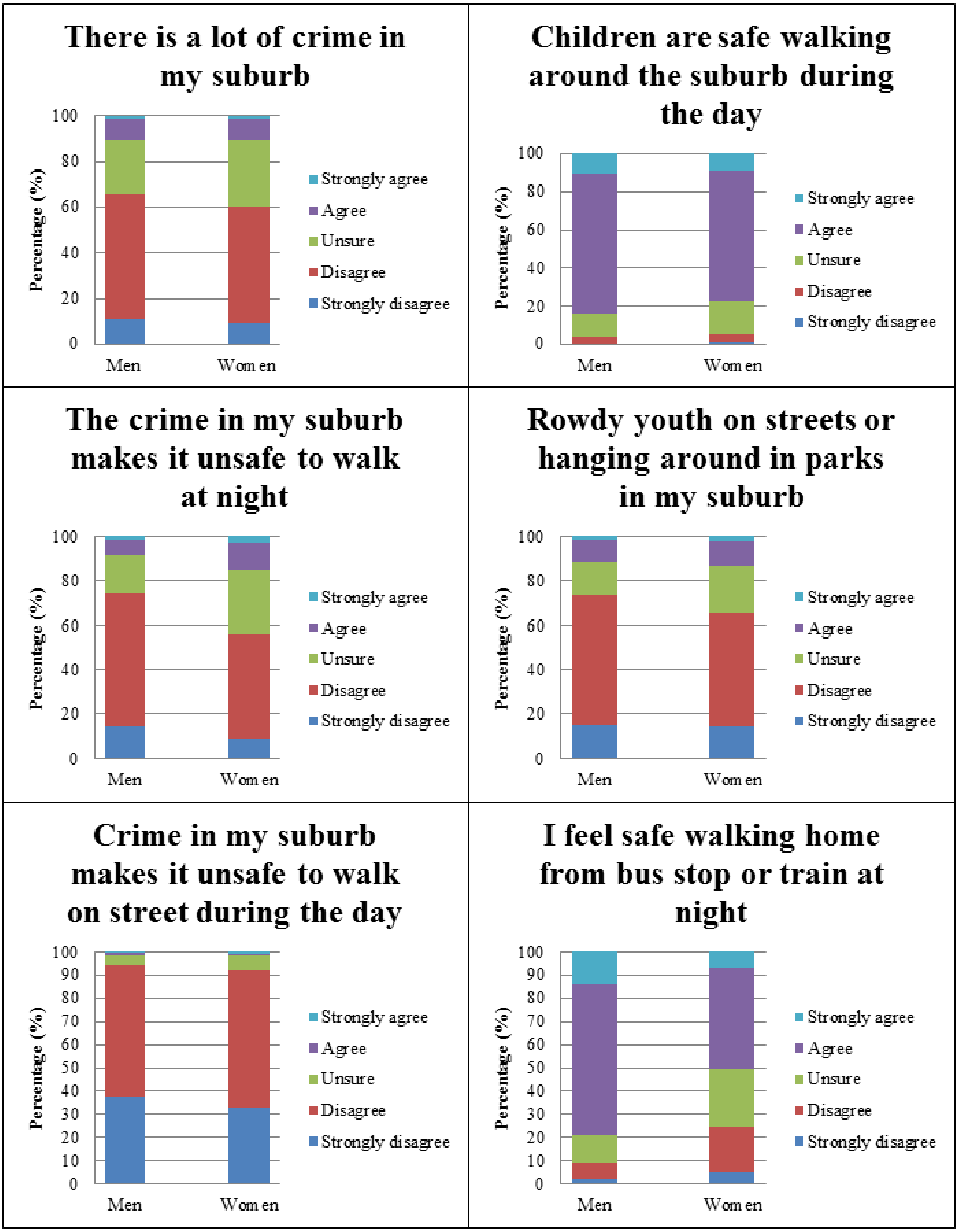

Figure 3.6: Percentage distribution of each item from the safety from crime statement by gender

Creating a neighbourhood-level measure of perceptions of safety from crime

The perception of safety from crime measure obtained from the HABITAT survey was measured at the individual-level. The aim of Study Two was to understand the contribution of the neighbourhood-level social environment in the relationship between neighbourhood disadvantage and physical function, as studies have shown that neighbourhood-level factors appear to play a comparatively greater role in shaping residents' behaviour than individual-level factors [236]. To estimate the perceptions of safety from crime at the neighbourhood-level, an Empirical Bayes Exchangeable (EBE) analysis was used. Instead of using a mean neighbourhood-level aggregated score, the EBE approach takes into account the number of participants in each neighbourhood, and the variability of the exposure within and between neighbourhoods [237]. Using this approach, the perception of safety from crime measure was considered independently distributed across neighbourhoods. The posterior mean of the random effect estimate, given the estimated variance components, was a weighted mean of the neighbourhood sample mean and overall mean. The EBE model assumed that this 'shrinkage' towards the overall mean removes bias that arises from the measurement error of the neighbourhood social process. It should be noted that spatial dependence was not considered because of the non-contiguity of the HABITAT neighbourhoods (i.e., neighbourhoods did not share a common boundary) included in the study. The following four steps were used to obtain the EBE estimate:

1. Generating a mean score of the perception of safety from crime in each neighbourhood included in the study ($\bar{Y}_{.j}$)
2. Using ANOVA model fitted using maximum likelihood to obtain estimates of the between- and within- neighbourhood variance. This was then used to obtain an estimate of the reliability of the exposure estimate $\hat{\lambda}_{Ej}$ for each neighbourhood

using Equation (2), where $\hat{\tau}_E$ is the between- neighbourhood variance, $\hat{\sigma}_e^2$ the within- neighbourhood variance, and n_j the number of people in each neighbourhood

3. Estimating the intercept $\hat{\gamma}_E$
4. Calculate the EBE estimate using Equation (3)

Equation (2):

$$\hat{\lambda}_{Ej} = \frac{\hat{\tau}_E}{(\hat{\tau}_E + \frac{\hat{\sigma}_e^2}{n_j})}$$

Equation (3):

$$\hat{\beta}_{EBEj} = \hat{\gamma}_E + \hat{\lambda}_{Ej}(\bar{Y}_{.j} - \hat{\gamma}_E)$$

This approach has been used in a previous HABITAT analysis to generate neighbourhood-level social environment variables [101]. The 200 HABITAT neighbourhoods were then grouped into quintiles for NPSC, with Q1 denoting the 20% neighbourhoods that are perceived as being the least safe from crime and Q5 the 20% neighbourhoods that are perceived as the safest from crime.

3.3.5 Built environment measures: Street connectivity, dwelling density, land use mix and walkability

As mentioned in previous section, spatial data were collected using GIS. Street connectivity, dwelling density, land use mix and a combined measure of these three variables (walkability) were used to represent the 'built environment' characteristics to address Aim 3 of this thesis. The data provided environmental measures within four types of geographical boundaries: (i) the one kilometre circular buffer surrounding each participant's residence; (ii) the HABITAT neighbourhood in which the participant resided; (iii) the Brisbane locality (suburb) of the participant's residence; and (iv) the network buffer. To understand the neighbourhood-level contribution of the built environment to the relationship between neighbourhood disadvantage and physical function, the chosen geographical boundary should ideally be consistent with the exposure (neighbourhood disadvantage). Therefore, for this PhD, the HABITAT neighbourhood in which participants resided was used to define the geographical boundaries.

The rationale to include both individual measure (street connectivity, dwelling density and land use mix) and the combined measure (walkability) was to overcome the possible limitations each measure may have pose in the analysis of how the built environment affects health. According to Grafova et al. [238], researchers who focus on a single built environmental feature may incorrectly attribute health effects to the wrong characteristics, and researchers who create indices by combining multiple features together may mask the features that matter most to health. Therefore, both single and combined measures were used to investigate Aim 3.

As recommended by Lamb and White [239], the built environment measures were analysed as continuous variables in the analysis. Although it is common for researchers to categorise built environment measures (e.g., binary split, tertiles, quartiles, quintiles or other levels of arbitrary categorisation), this often leads to loss of information, lack of replicability between studies, and potential bias due to choice of cut-point [239]. Each of the built environment measures used in this thesis is described below.

Street connectivity

Street connectivity (or intersection density) was measured as the count number of four-way or more intersections within the HABITAT neighbourhoods. The mean number of four-way intersections per neighbourhood was 2.94 (standard deviation of 2.37) per neighbourhood and counts ranged from 0 to 12.

Dwelling density

Dwelling density was defined and calculated as the total number of dwellings per hectare of residential land within the neighbourhoods. Larger numbers represented greater density. The mean dwelling density was 1,778 (standard deviation of 754) per neighbourhood, with a range from 20 to 4,900.

Land use mix

Land use mix was calculated using five classifications of land use: commercial, industrial, leisure/recreation, residential and other. The formula used to calculate this variable was adopted from Leslie et al. [240]. The sum of land area in the HABITAT neighbourhood boundary was used to create an entropy score for each neighbourhood, calculated via Equation (4), where k represents the category of land use; p represents the proportion of land area that is devoted to a specific land use and N represents the number of land use categories:

Equation (4):

$$-\frac{\sum_k (p_k \ln p_k)}{\ln N}$$

The entropy equation results in a score of 0–1, whereby 0 represents homogeneity (all land uses are of a single type), and 1 represents heterogeneity (i.e., where there is an even distribution of each of the five land use categories). The mean land use mix was 0.35 (standard deviation of 0.23) per neighbourhood, ranging from 0 to 0.91.

Walkability index

The walkability index was calculated using street connectivity, dwelling density and land use mix. Each measure was standardised and summed for each HABITAT neighbourhood to generate a walkability index. This type of index has been extensively validated [193, 241, 242]. Due to the inconsistencies in the literature, no weighting was applied in the development of the walkability index [243]. The mean walkability index was 0.003 (standard deviation of 1.81) per neighbourhood.

3.3.6 Physical activity: Walking

As previously mentioned, LTPA and TRPA should be examined separately, as each domain is influenced by different characteristics of the neighbourhood environment [171]. Even though the HABITAT study measures many physical activity outcomes (e.g., total frequency and time of physical activity per week, total time of vigorous activity per week, total time cycling for recreation and transport per week), total time spent walking for recreation (WfR) and walking for transport (WfT) per week were selected for analysis for this thesis. WfR and WfT were considered appropriate for this project for three reasons: first, walking is the most common exercise undertaken among older adults [170]; second, walking is the most relevant physical activity domain in neighbourhood studies [244]; and third, walking can be easily promoted as a public health intervention, because it is free and can be easily incorporated into everyday lives [245].

Walking for recreation

Table 3.6 presents the question that asked participants about their recreational walking over the past week in hours and minutes. To minimise the measurement error that may result from over-reporting, the time data were truncated to a maximum of 840 minutes per week (equivalent to two hours per day) [223]. Due to the zero-inflated distribution of this variable, the level of WfR per week was categorised as none, low (1–149 minutes) and moderate to high (at least 150 minutes or more). The cut-point for the moderate to high category was consistent with the physical activity guidelines, which recommended at least 30 minutes of moderate activity, five days per week (equivalent to 150 minutes per week) [223].

In the HABITAT wave 4 data, about 60% of the sample undertook recreational walking, and women were more likely to report that they walked for recreational purposes than men (women: 30.6%; men: 27.7% in the 150 minutes and above category; $p < 0.05$) (Figure 3.7).

Table 3.6: Question about duration of walking for recreation in the past week

This question is about walking for RECREATION, LEISURE OR EXERCISE. When answering this question, please DO NOT count walking for transport		
What do you estimate was the total time that you spent walking for recreation, leisure or exercise in the LAST WEEK?	Hours	Minues
If NONE, please write 0		

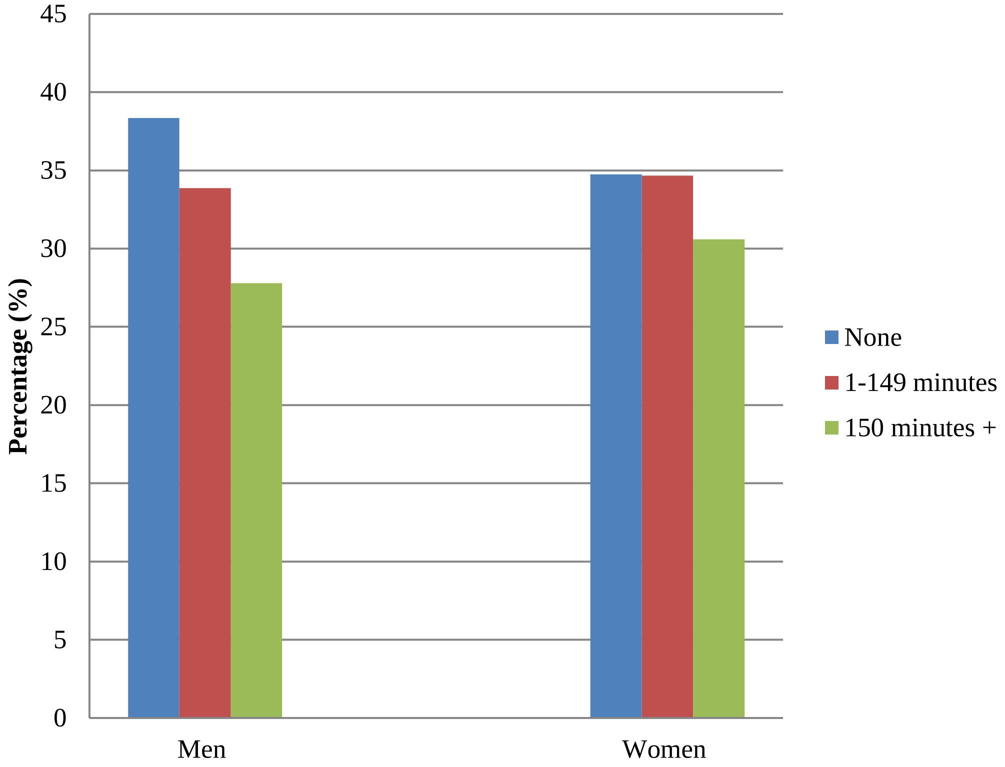

Figure 3.7: Percentage distribution of recreational walking by gender in 2013 (wave 4 of the HABITAT study)

Transport walking

Table 3.7 presents the question that asked participants about transport walking over the past week in hours and minutes. Similar to recreational walking, outlier values were top-coded to 840 minutes per week. The distribution of the transport walking variable was zero-inflated (60% of the sample were 'non-transport walkers'), and only 6% of the sample reported that they walked more than 150 minutes per week. Due to the small proportion of the sample being in the moderate to high category for transport walking, the transport walking variable was re-coded as a binomial outcome (None/Yes). Figure 3.8 presents the percentage distribution of transport walking for men and women. A greater proportion of men reported walking for transport compared with women (men: 42.8%, women: 38.3%, chi-square $p < 0.001$).

Table 3.7: Question about duration of walking for transport in the past week

This question is about walking for TRANSPORT. Transport includes things like travel to and from work, to do errands, or to go from place to place. When answering this question, please DO NOT count walking for exercise or recreation.		
What do you estimate was the total time that you spent walking for transport in the LAST WEEK?	Hours	Minutes
		If NONE, please write 0

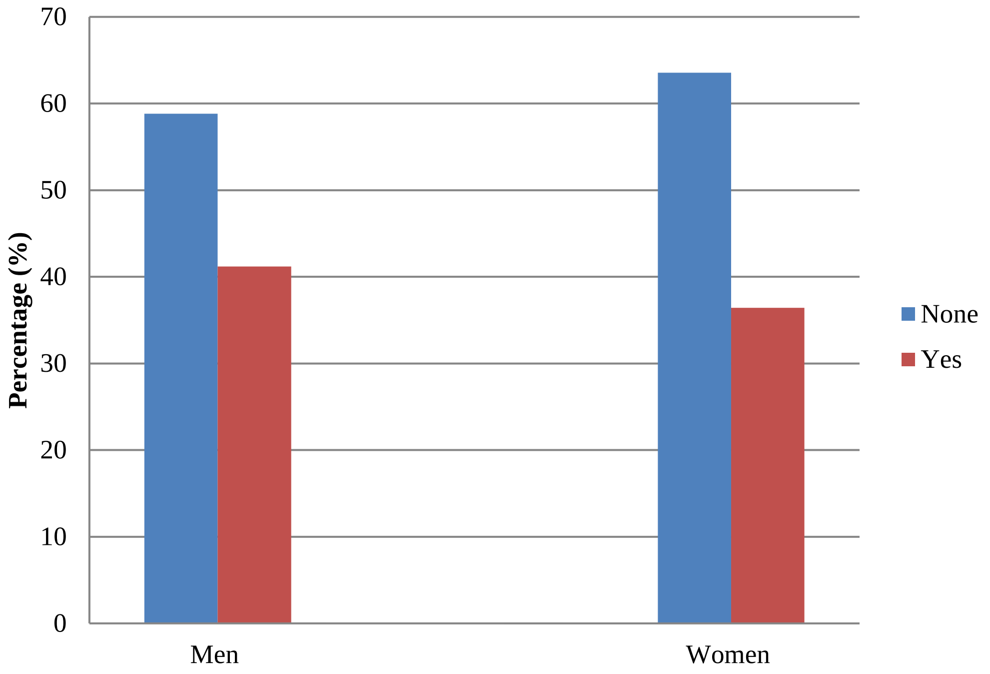

Figure 3.8: Percentage distribution of transport walking by gender in 2013 (wave 4 of the HABITAT study)

3.3.7 Individual-level socioeconomic position

Socioeconomic position (SEP) indicators provide information about an individual's capacity to access social and economic resources [246]. Education, occupation and income are the three most common indicators of SEP in public health research and they have been shown to be associated with a wide range of health outcomes [247, 248]. While the dimensions of SEP that these indicators capture are likely to be strongly correlated, it is also likely that each reflects different individual and societal factors associated with health [246]. For example, measures of occupation are likely to signify prestige, work exposure and responsibility, while measures of income are likely to reflect quality of diet, and health seeking behaviours [247]. Dutton et al. [249] and Geyer et al. [250] have suggested that education, occupation and income cannot be used interchangeably in social epidemiological research, as different indicators of SEP measure different causal mechanisms between exposure and outcome. To obtain a comprehensive understanding of inequalities and health, the use of several indicators of SEP are recommended [251, 252]. Therefore, for this PhD, education, occupation and household income were included to indicate individual-level SEP.

Education

Education has been considered as one of the most basic components of SEP because of its potential to influence an individual's future occupation and earning potential [253]. There are several possible mechanisms by which education might influence behaviour and health. For example, education about diet and nutrition provides knowledge that allows people to make informed decisions about food consumption that can be beneficial to health. Individuals with higher levels of education may also be more likely to secure better work with higher income [253]. The advantages of using a measure of education are stability (less likely to change over time), comparability across countries, and ease of measurement. On the other hand, the disadvantage of this measure is its inability to capture quality of education. To obtain the education measure, HABITAT respondents were asked to indicate the highest qualification they had attained at the time of completing the survey (Table 3.8).

Table 3.8: Question about education attainment

What is the highest qualification you have completed?	
Tick one only	
Year 9 or less	
Year 10 (Junior/4th form)	
Year 11 (Senior/5th form)	
Year 12 (Senior/6th form)	
Certificate (trade or business)	
Diploma or Associate Degree	
Bachelor Degree (Pass or Honours)	
Graduate Diploma or Graduate Certificate	
Postgraduate degree (Master degree or Doctorate)	
Other (please describe)	

Consistent with previous published papers using the education variables from the HABITAT data [56, 57, 97, 177], education attainment was collapsed into four categories:

(i) Bachelor Degree or higher: Bachelor degree, Graduate Diploma or Graduate Certificate, Postgraduate degree

(ii) Diploma/ Associate Degree

(iii) Certificate (Trade/Business)

(iv) None beyond school: Year 12 or less.

In the HABITAT wave 4 sample, a large proportion of men (36%) had obtained a bachelor degree, while a large proportion of women (40%) did not have any educational qualifications beyond secondary school (Figure 3.9).

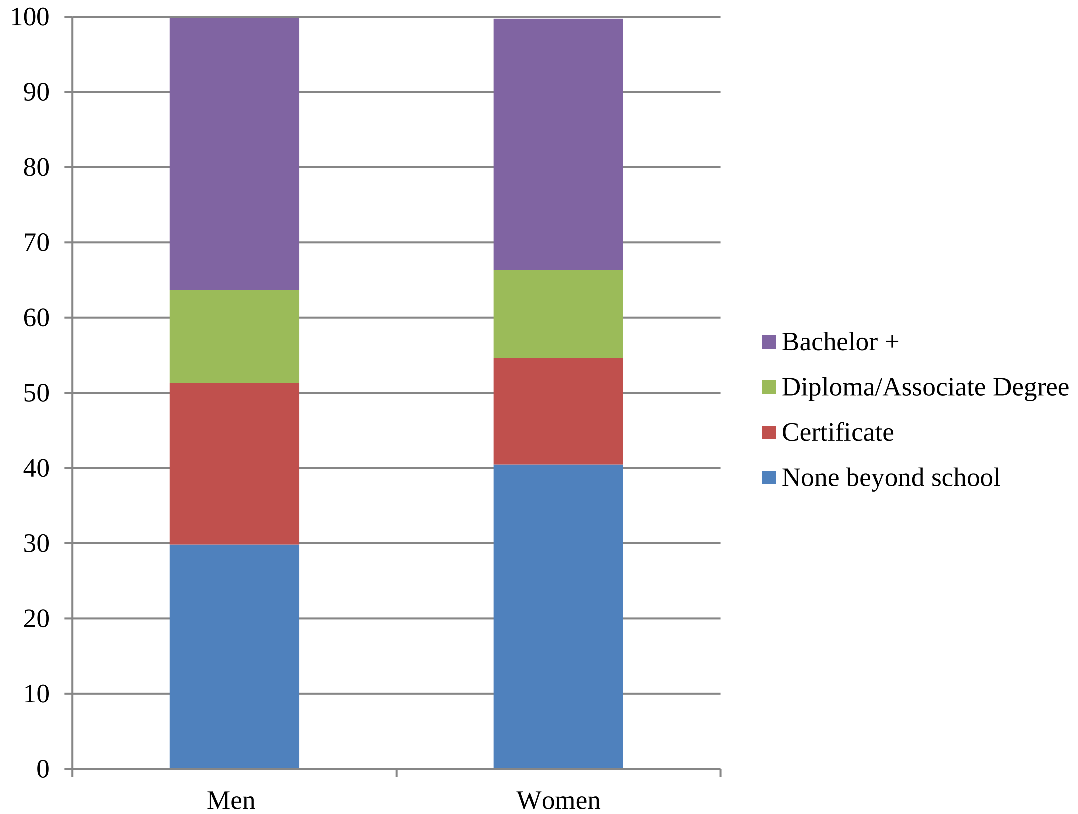

Figure 3.9: Percentage of education attainment by gender in 2013 (wave 4 of the HABITAT study)

Occupation

Occupation-based indicators are generally used to define individuals' access to resources and exposure to physical hazards and psychological risks [254]. This indicator is strongly related to income and changes over the life-course [255]. However, occupation is often subject to reverse causation (when a person is ill, they are unable to work) and is difficult to classify, especially for those who are unemployed, retired or undertake home duties [246]. In the HABITAT study, to obtain an occupation measure, respondents were asked to indicate their current employment status, and if employed, the full title of their occupation (Table 3.9, 3.10).

Table 3.9: Question about employment situation

Which one of the following best describes your current employment situation?	
Please tick one number only	
Full time paid work in a job, business or profession	
Part time paid work in a job, business or profession	
Casual paid work in a job, business or profession	
Work without pay in family or other business	
Home duties not looking for work	
Unemployed looking for work	
Retired	
Permanently unable to work	
Student	
Other (please specify)	

Table 3.10: Question about current occupation

What is your current occupation? (If you have more than one job, we are interested in your main job).	
Please give full title (for example: Childcare Aide, Maths Teacher, Pastry cook, Commercial Airline Pilot, Apprentice Toolmaker etc). For Public Servants, state official designation and occupation. For armed services personnel, state rank and occupation	
Full title of occupation:	

The occupation data provided by respondents were subsequently coded to the Australian Classification of Occupation (ASCO) [256]. The ASCO represents a skilled-based measure and categorises occupations according to the levels of knowledge required, materials on which people work, tools and equipment used and services produced. These occupational groupings are hierarchically ordered, and based on the relative skill levels across these various dimensions. Occupations that have the most extensive skill requirements are positioned at the top of the hierarchy. The ASCO classifies nine major occupation groups, and each has a skill level based on the criteria defined in the Australian Qualifications Framework (AQF) [257]. Detailed descriptions of the different AQF levels can be found in the *Australian Qualification Framework Implementation Handbook* released by the AQF Advisory Board [257]. Table 3.11 shows the assignment of skill levels for the nine major groups.

Table 3.11: The assignment of skill level based on the major groups by the Australian Qualification Framework

ASCO classification	**Major Group**	**Skill level**
1	Managers and Administrators	1
2	Professionals	1
3	Associate Professionals	2
4	Tradespersons and Related Workers	3
5	Advanced Clerical and Service Workers	3
6	Intermediate Clerical, Sales and Service Workers	4
7	Intermediate Production and Transport Workers	4
8	Elementary Clerical, Sales and Service Workers	5
9	Labourers and Related Workers	5

For the purpose of this PhD, the original nine-level ASCO classifications were re-coded into three categories:

(i) Manager/professionals: Major groups 1, 2 and 3

(ii) White collar employees: Major groups 5, 6 and 8

(iii) Blue collar employees: Major groups 4, 7 and 9.

Collapsing the original ASCO grouping to three categories has been used by other Australian researchers, who have established that the occupation categories are sufficiently sensitive to enable differentiation between occupation groups in terms of a range of health behaviours and outcomes [248, 258].

Respondents who were not employed were categorised as follows:

(iv) Home duties

(v) Retired

(vi) Permanently unable to work

(vii) Not easily classifiable (NEC): unemployed, students, other or missing.

As depicted in Figure 3.10, the highest proportion of men and women in the HABITAT wave 4 sample were employed in the professional/manager positions. There were some gender differences in their occupation profiles: higher proportions of women were employed as white collar and being in home duties, whereas higher proportions of men were employed as blue collar (chi-square $p < 0.05$).

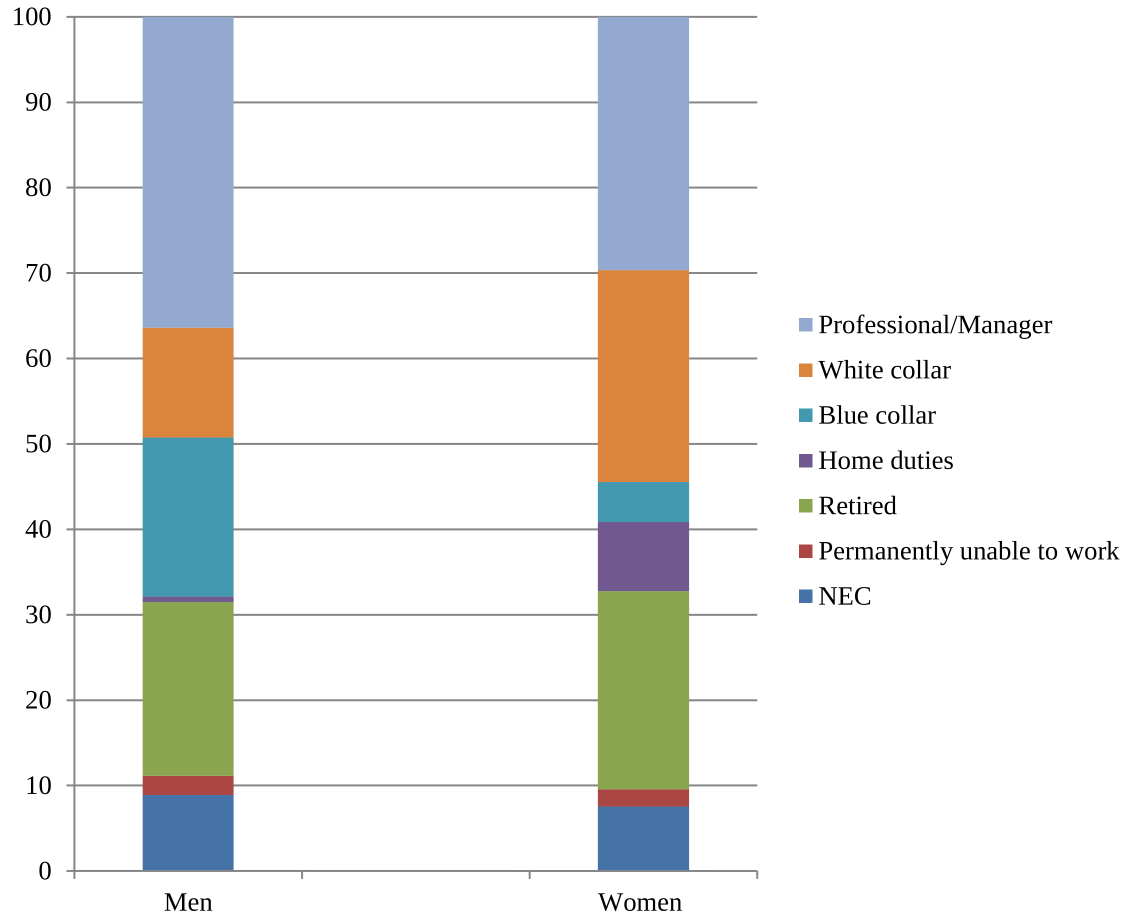

Figure 3.10: Percentage distribution of occupation status by gender in 2013 (wave 4 of the HABITAT study)

Household income

Household income is a quantification of individuals' or household material resources [246, 253]. As with education and occupation, household income can influence a wide range of material circumstances with direct and indirect implications for health, including access to shelter, food and health services. The limitations of this indicator are that it is subject to reverse causation and has a higher non-response rate than education and occupation [246, 259]. To obtain the household income measure, HABITAT respondents were asked to indicate their household income either per year, per fortnight or per week (Table 3.12).

Table 3.12: Question about household income either per year, per fortnight or per week

Please add up the amount of BEFORE TAX income received by ALL members of your household, and tick the box that comes closest to this number. Please indicate income either per year, per fortnight or per week.							
Tick one box only							
Per year			Per fortnight			Per week	
	Less than $15,599			Less than $600			Less than $300
	$15,600-20,799			$600-799			$300-399
	$20,800-25,999			$800-999			$400-499
	$26,000-31,199			$1,000-1,199			$500-599
	$31,200-36,399	OR		$1,200-1,399	OR		$600-699
	$36,400-41,599			$1,400-1,599			$700-799
	$41,600-51,999			$1,600-1,999			$800-999
	$52,000-72,799			$2,000-2,799			$1000-1,399
	$72,800-93,599			$2,800-3,599			$1,400-1,799
	$93,600-129,999			$3,600-4,999			$1,800-2,499
	$130,000 or more			$5,000 or more			$2,500 or more
	Don’t know						
	Don’t want to answer this						

For the purpose of this PhD, the 14- category measure of household income was subsequently recoded into 6 groups:

(i) $130,000 or more

(ii) $72,800-129,999

(iii) $52,000-72,799

(iv) $26,000-51,599

(v) Less than $25,999

(vi) Not easily classifiable (NEC): Missing/ Don’t know/ Don’t want to answer this

In the HABITAT wave 4 sample, about 50% of men reported that they were a member of household earning $72,800 and above per year (Figure 3.11).

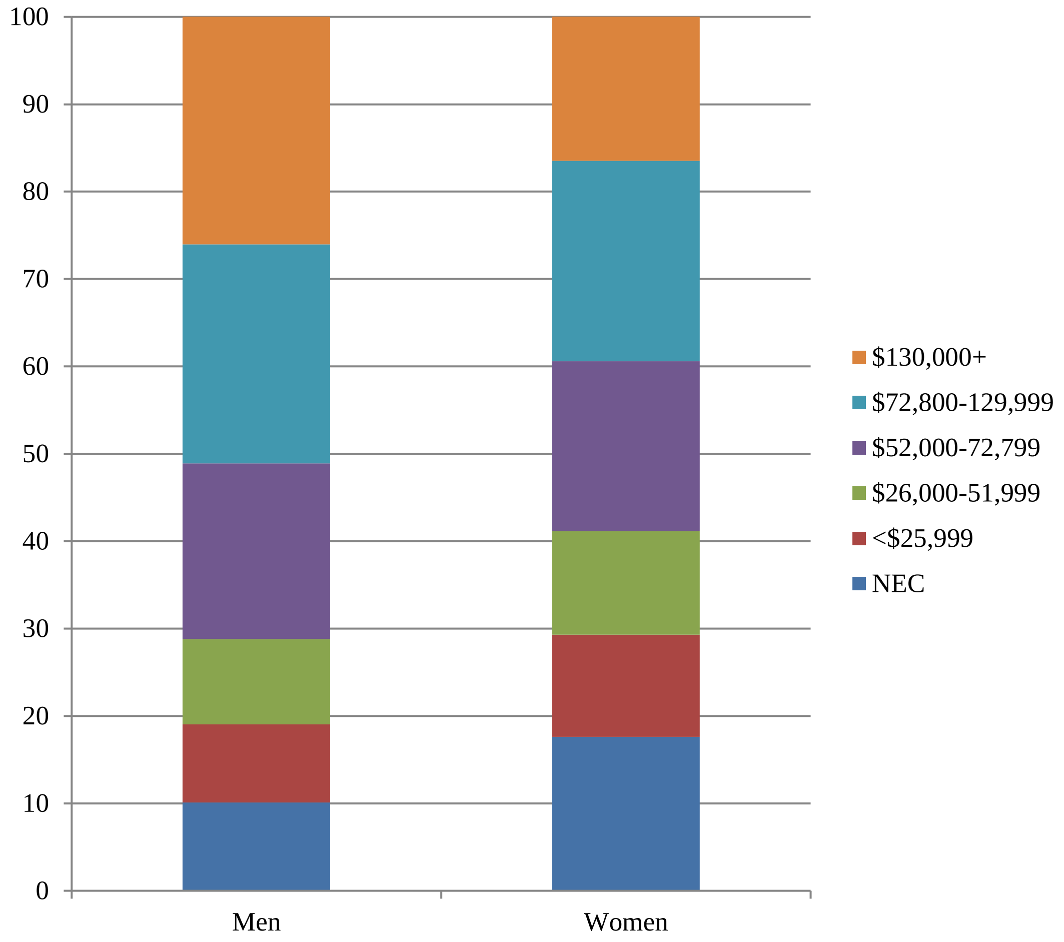

Figure 3.11: Percentage distribution of household income groups by gender in 2013 (wave 4 of the HABITAT study)

3.3.8 Demographic information

Age

The target population for the HABITAT study and for this thesis was middle-aged to older adults. Research has shown that many individuals within this age group begin to experience the onset of chronic disease and functional decline [260]. In the HABITAT wave 4 sample the mean age was 58 years, and ranged between 45-71 years. For the purpose of this PhD, the age variable was categorised into 5 groups:

(i) 45–49 years

(ii) 50–54 years

(iii) 55–59 years

(iv) 60–65 years

(v) 66 years and older

The percentage distribution of age groups by gender is presented in Figure 3.13.

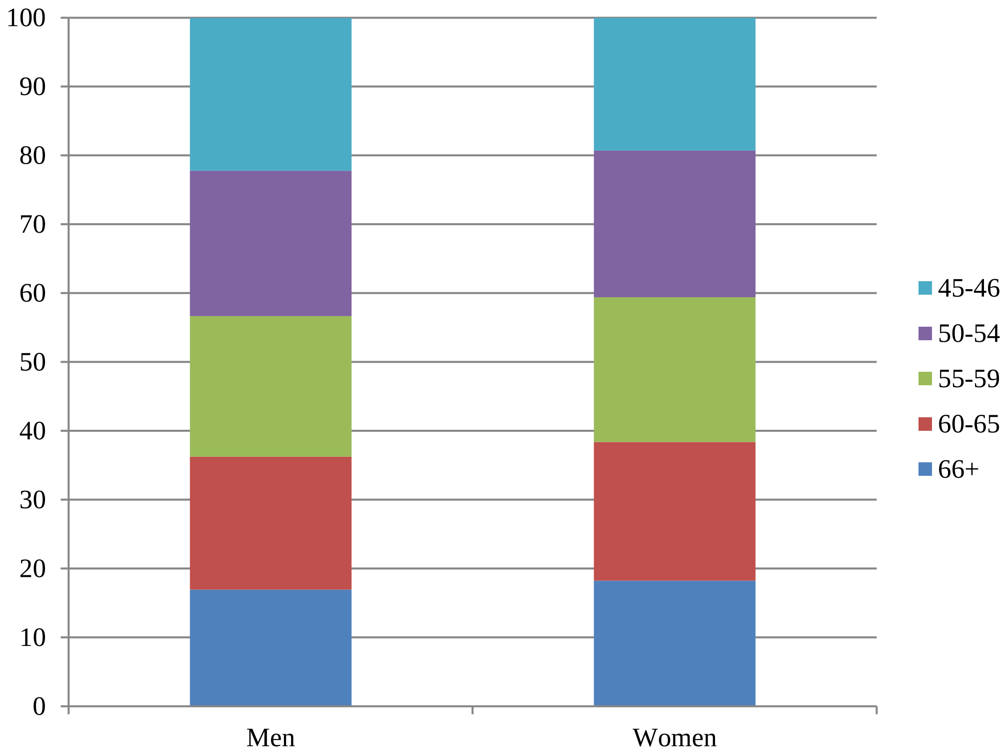

Figure 3.12: Percentage distribution of age groups by gender in 2013 (wave 4 of the HABITAT study)

Gender

In the HABITAT wave 4 sample, the proportion of men and women was 42% and 58%, respectively. As mentioned previously, there are gender difference in response to environmental contexts (women perceive more risk in their environment than men) as well as physical function profile [42, 261]. Therefore, all analyses in this thesis are stratified by gender.

3.4 Snapshot comparison of sample characteristics between wave 1 (baseline 2007) and wave 4 (2013)

Table 3.13 presents some key socioeconomic characteristics of the HABITAT wave 4 sample and compares them with the HABITAT baseline sample in 2007 (which closely reflects the Brisbane population). The socioeconomic characteristics of the samples in waves 1 and 4 were similar except for occupation—a large proportion of wave 4 sample has transitioned to retirement (8.3% in wave 1 versus 21.9% in wave 4). The mean physical function scores were patterned by socioeconomic status. Those living in the most disadvantaged neighbourhoods, those with the lowest education attainment, those who were permanently unable to work and those with household income of less than $25,999 had lower physical function scores than their counterparts in higher SEPs.

Table 3.13: Characteristics of the sample and mean physical function scores

	Wave 1 (2007) N=11,035	Wave 4 (2013) N=6,520	Physical function score[a] (Wave 4)	
	%	%	Mean	95% CI
Gender				
Men	43.9	42.4	87.51	86.85, 88.17
Women	56.1	57.6	83.36	82.71, 84.01
Neighbourhood disadvantage				
Q1 (least disadvantage)	29.5	27.1	87.60	86.80, 88.40
Q2	19.6	24.5	87.69	86.86, 88.51
Q3	17.0	18.2	85.30	84.24, 86.36
Q4	20.5	17.4	82.94	81.78, 84.09
Q5 (most disadvantage)	13.4	12.9	77.67	75.96, 79.38
Education				
Bachelor degree +	31.3	34.0	88.42	87.74, 89.10
Diploma/Associate degree	11.5	11.7	86.51	85.28, 87.73
Certificate	17.7	16.9	84.97	83.82, 86.13
None beyond school	39.1	35.4	81.58	80.69, 82.46
Occupation				
Manager/Professional	32.6	32.5	90.56	89.98, 91.14
White collar	21.6	19.7	87.71	86.85, 88.56
Blue collar	13.8	10.6	87.78	86.53, 89.03
Home duties	5.4	4.9	82.85	80.60, 85.10
Retired	8.3	21.9	78.60	77.48, 79.73
Permanently unable to work	2.7	2.1	47.68	42.62, 52.75
Not easily classifiable	15.4	8.1	81.88	79.97, 83.78
Household income				
$130,000+	17.1	20.5	91.79	91.10, 92.48
$72,800-12,999	25.8	23.8	88.04	87.25, 88.83
$52,000-72,799	22.1	19.7	85.87	84.65, 87.10
$26,000-51,999	10.7	10.9	80.56	79.37, 81.75
Less than $25,999	9.5	10.5	73.40	71.52, 75.29
Not easily classifiable	14.7	14.4	84.36	83.02, 85.71

Note: [a]Physical function score from 0–100, 0 indicates minimal function, 100 indicates maximal function.

3.5 Survey dropout (attrition) between Wave 1 and Wave 4

An attrition analysis was conducted to identify the characteristics of individuals who dropped out of the HABITAT study between waves 1 and 4. The analysis revealed that gender, education, occupation and household income were significantly associated with the odds of attrition (Table 3.14). The odds of dropping out between wave 1 and wave 4 were less likely for women and the retired, but higher for those with lower education status (diploma, certificate and none beyond school), those permanently unable to work and those with a lower household income ($51,999 or less per annum). The higher odds of attrition among individuals from more socioeconomically disadvantaged groups may produce biased estimates, and this is discussed in the limitation section in Chapter 7. As the outcome of this study (physical function) is only measured at wave 4, the cause of attrition was difficult to identify. Therefore, for all the analyses in the studies, complete case analysis was considered.

Table 3.14: The odds of dropping out of the HABITAT study between wave 1 and wave 4 by respondents' sociodemographic characteristics.

	Odds of attrition OR (95% CrI)
Gender	
Male	1.00
Female	**0.84 (0.77, 0.91)**
Neighbourhood disadvantage	
Q1 (least disadvantage)	1.00
Q2	0.95 (0.85, 1.07)
Q3	1.11 (0.98, 1.26)
Q4	0.97 (0.86, 1.09)
Q5 (most disadvantage)	1.10 (0.94, 1.29)
Education	
Bachelor degree +	1.00
Diploma/Associate degree	**1.16 (1.01, 1.34)**
Certificate	**1.25 (1.11, 1.41)**
None beyond school	**1.43 (1.28, 1.58)**
Occupation	
Manager/Professional	1.00
White collar	1.03 (0.92, 1.17)
Blue collar	1.15 (0.99, 1.33)
Home duties	1.01 (0.83, 1.22)
Retired	**0.69 (0.58, 0.82)**
Permanently unable to work	**1.34 (1.03, 1.76)**
Not easily classifiable	0.97 (0.84, 1.11)
Household income	
$130,000+	1.00
$72,800-12,999	0.96 (0.84, 1.10)
$52,000-72,799	1.05 (0.90, 1.22)
$26,000-51,999	**1.29 (1.09, 1.52)**
Less than $25,999	**1.33 (1.11, 1.59)**
Don't know/ Don't want to answer this	**1.83 (1.54, 2.16)**

Note: Data adjusted for gender, neighbourhood disadvantage, education, occupation and household income

3.6 Analytic strategy

The large scale and representative nature of the HABITAT's two stage sampling method resulted in a hierarchical data structure. As described earlier, data were collected at the individual- and neighbourhood-level. At the commencement of this PhD program, the main outcome (physical function) was only collected at one time point (wave 4), thus, only cross-sectional analysis could be undertaken for this thesis.

In this thesis by publication, each individual study required its own unique analytic approach; specifically suited to the research question and guided by what has been undertaken previously in the field. To this end, a one-size-fits-all analytical approach would be inappropriate. The analytic approach for each individual study is deliberated upon and documented in the methods section of each of the papers which are presented as Chapters 4 to 6. Therefore, the following section therefore details a broad assortment of approaches and techniques suited to dealing with clustered data structures.

Multilevel analysis is the appropriate statistical technique to be used in this program of research. Multilevel modelling in this thesis had a single outcome measure, namely, physical function, and several independent or explanatory variables, at both individual and neighbourhood levels. This analytical strategy has the capacity to predict the direction and strength of the relationship at multiple levels [262]. In addition, a multilevel model is able to isolate the independent effect of neighbourhood attributes from the effect of individual-level attributes [263, 264].

In general, multilevel regression models (linear, binomial or multinomial) were employed to examine the association between neighbourhood environment, physical activity and physical function. In instances where multilevel categorical models were undertaken, Markov chain Monte Carlo (MCMC) simulation was used to estimate odds ratio and 95% credible intervals. This estimation approach for multilevel logistic models was recommended by Browne and Rasbash [265] and was implemented using the Metropolis-Hasting algorithm with standard non-informative prior distribution on all parameters. The MCMC method is a simulation-based procedure. Rather than simply producing point estimates, the MCMC runs multiple iterations and then at each iteration, an estimate for each unknown parameter is produced. In order to achieve convergence of the simulated chains for the variance parameters, the Raftery-Lewis and Brooks-Draper diagnostics are calculated. The calculation was based on two quantiles (the defaults being the 2.5% and 97.5% quantiles) that formed a central interval estimate. In Study Two and Study Three (Chapters 5 and 6), where MCMC was employed, the Metropolis–Hastings algorithm was implemented for 50,000 iterations.

All data analysis was performed using MLwiN 2.3 [266] and STATA SE 13 [267].

3.7 Modelling strategy

A Directed Acyclic Graph (DAG) was constructed to guide the modelling strategy used in this thesis. A DAG is a graphical representation that depicts and summarises knowledge and assumed relationships in an intuitive manner. A set of DAG rules has been described by Pearl [268], Greenland et al. [269] and Hernán et al. [270]. Briefly, DAGs consist of edges or arrows that are directed, linking nodes (between variables) and their paths. Using the DAG approach, causation or association is indicated by an arrow connecting two variables. The absence of an arrow between variables indicates independence or no causal association. All shared causes of any pair of variables must be included for a diagram to represent a causal system, regardless of the data availability.

DAGs represent the causal determinants of statistical associations, common prior causes (i.e., confounders) and common effects (i.e., colliders). Therefore, DAGs are useful for identifying which variables should be included or adjusted for in statistical analyses to minimise the extent of bias in the estimate produced. Traditionally, when a variable is associated with the exposure and outcome, that variable is considered to be a confounder and it should be adjusted for. However, adjustment for all possible confounders may introduce conditional associations, also known as collider bias or confounding bias.

For this PhD thesis, a *general* DAG was constructed to show the contextual relationship between neighbourhood environment, physical function, age, sex, individual-level SEP and potential confounders (Figure 3.13). Based on the conceptual framework developed in the previous chapter, the variables of interest in this thesis were neighbourhood environment (neighbourhood socioeconomic disadvantage, neighbourhood safety from crime and neighbourhood built environment), walking (recreational walking and transport walking) and physical function. In the DAG, the neighbourhood environment is the exposure, physical function is the outcome of interest and walking is the covariate of interest. Many of the factors associated with each variable of interest, regardless of whether they were collected in the HABITAT data, were identified and included in the DAG.

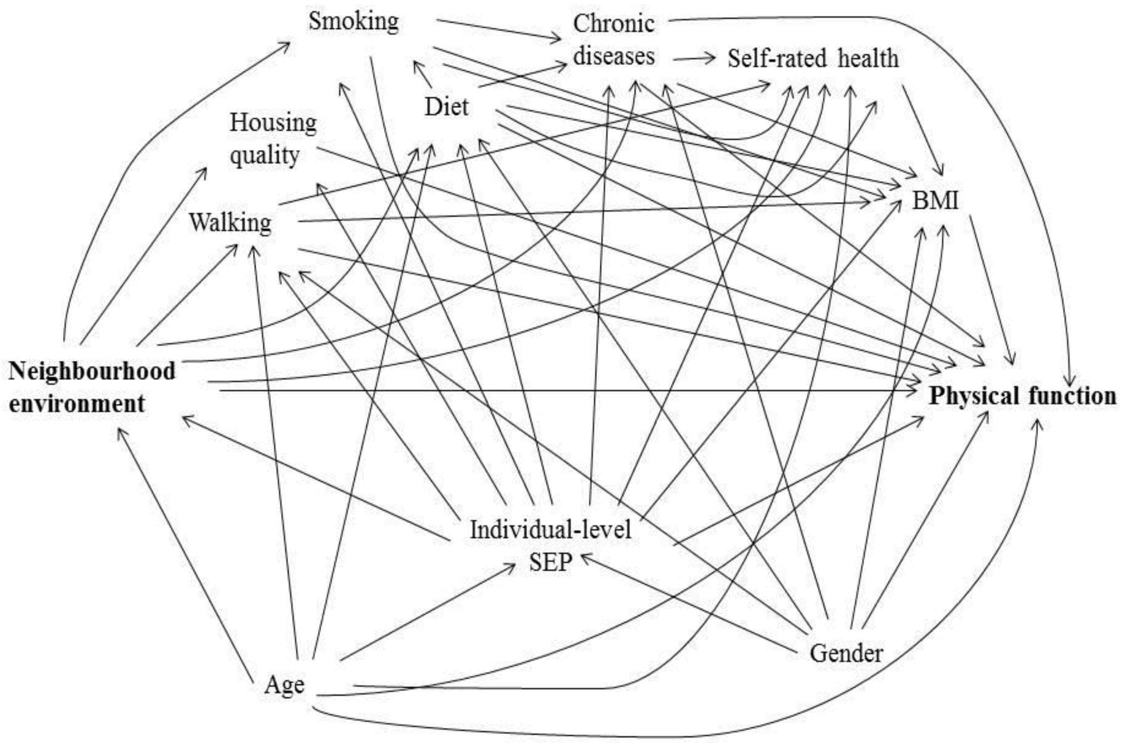

Figure 3.13: Directed acyclic graph conceptualising the relationship between neighbourhood environment and physical function

The model implies that neighbourhood environment has a relationship with physical function, and that neighbourhood environment also has a relationship with physical function through walking, housing quality, smoking, diet, chronic disease, self-rated health and body mass index (BMI) (among other factors). Based on the DAG rules [269], the minimum adjustment sets for estimating the direct relationship between neighbourhood environment and physical function were age, sex and individual-level SEP. Walking, housing quality, smoking, diet, chronic disease, self-rated health and BMI were the intermediate variables between neighbourhood environment and physical function. Rothman and Greenland [271] have suggested that adjusting for intermediate variables would usually result in bias and may be viewed as a form of over-adjustment, defined as ‘statistical adjustment by an excessive number of variables, uninformed by substantive knowledge that can obscure a true effect or create an apparent effect when none exists' [272]. Therefore, these intermediate variables were not adjusted in analyses unless they were variables of primary interest—in this case, walking. DAGs were constructed for each research aim in the PhD thesis. Therefore, each had their own minimum sets of adjustment in the modelling.

3.8 Conclusion

This chapter outlined the methodological framework underpinning this thesis research, including the data source, data collection, variables used and analytical approaches, as well as complementary information not included in each of the publications. The following three chapters (one published and one under review and one submitted for publication) present the quantitative findings based on the methodological approaches described above.

Chapter 4: Neighbourhood disadvantage, individual-level socioeconomic position and physical function: A cross-sectional multilevel analysis

This chapter presents Study One of this thesis. Study One examined the relationship between neighbourhood disadvantage and physical function among middle-aged to older adults in Brisbane, Australia. The findings of this study described the direction and magnitude of the association between neighbourhood disadvantage, individual-level socioeconomic position and physical function; and further examined whether the relationship between individual-level socioeconomic position and physical function differs by level of neighbourhood disadvantage. This chapter has been published in Preventive Medicine.

Citation:

Loh VH, Rachele JN, Brown WJ, Washington S, Turrell G. 2016. Neighbourhood disadvantage, individual-level socioeconomic position and physical function: A cross-sectional multilevel analysis. Prev Med 89:112-120.

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4.1 Abstract

Understanding associations between physical function and neighbourhood disadvantage may provide insights into which interventions might best contribute to reducing socioeconomic inequalities in health. This study examines associations between neighbourhood-disadvantage, individual-level socioeconomic position (SEP) and physical function from a multilevel perspective. Data were obtained from the HABITAT multilevel longitudinal (2007-13) study of middle-aged adults, using data from the fourth wave (2013). This investigation included 6,004 residents (age 46-71 years) of 535 neighbourhoods in Brisbane, Australia. Physical function was measured using the PF-10 (0 – 100), with higher scores indicating better function. The data were analysed using multilevel linear regression and was extended to test for cross-level interactions by including interaction terms for different combinations of SEP (education, occupation, household income) and neighbourhood disadvantage on physical function. Residents of the most disadvantaged neighbourhoods had significantly lower function (men: β -11.36 95% CI -13.74, -8.99; women: β -11.41 95% CI -13.60, -9.22). These associations remained after adjustment for individual-level SEP. Individuals with no post-school education, those permanently unable to work, and members of the lowest household income had significantly poorer physical function. Cross-level interactions suggested that the relationship between household income and physical function is different across levels of neighbourhood disadvantage for men; and for education and occupation for women. Living in a disadvantaged neighbourhood was negatively associated with physical function after adjustment for individual-level SEP. These results may assist in the development of policy-relevant targeted interventions to delay the rate of physical function decline at a community-level.

4.2 Introduction

Physical function is defined as difficulty in performing activities that require physical capacity, ranging from activities of daily living (e.g., housework, shopping, walking and climbing stairs) to more vigorous activities that require increasing degrees of mobility, strength or endurance [273]. Difficulty with physical function, represented by the inability to perform usual activities of everyday life, is a serious problem among older persons [38, 78, 274]. The magnitude of this problem is likely to become considerably greater with continuing increases in longevity and in the size of the oldest population in most developed countries [274, 275]. In addition, physical function is associated with an increased risk of falling, cognitive decline and all-cause mortality [274].

According to the World Health Organization [276], the rate of physical function decline is not typically the result of a single cause, but arises from an interaction of risk factors in various domains, both individual and environmental. Traditionally, research on the determinants of physical function has been based on individual-level factors [20, 277-279]. More recently, interest in the effects of neighbourhood context on physical health has received growing attention; and multiple studies have shown that poor health is partly a function of residing in socioeconomically disadvantaged areas [60, 91, 108]. Research suggests that the external environment, such as the neighbourhood, is of particular importance for physical function in older adults as they tend to have a longer duration of exposure to neighbourhood influences than younger individuals, possibly due to retirement [280]. Older adults are also a sub-group with declining physical and mental health, shrinking social networks, loss of social support and increased fragility that may reduce their ability to cope with environmental demands [280]. It is possible that heterogeneity in physical function among this group may be explained by both individual-and neighbourhood-level factors, underlining the importance of any associations between physical function and neighbourhood characteristics [80].

Several studies (three single-level and one multi-level) [119-122] have examined the association between neighbourhood disadvantage and physical function. Findings from these studies are mixed. Among the single-level studies, one [121] found no association between neighbourhood disadvantage and physical function, while the other two [119, 122] showed that residents of socioeconomically disadvantaged neighbourhoods exhibited lower function than their counterparts from more advantaged neighbourhoods. However, these two ecological studies used data that were aggregated to a single geographical scale, hence they couldn't provide a quantification of the variation between areas, or show whether and how much of the variation was due to the clustering of individuals (a compositional effect) or the environmental characteristics of the areas (a contextual effect). Given the lack of multilevel studies, the question of whether the neighbourhood socioeconomic environment influences physical function after adjustment for individual-level socioeconomic position (SEP) remains. The only known multilevel study of neighbourhood disadvantage and physical function [120] found no significant association between these factors; and whilst this work provided an important advancement in this field, the study assumed a uniform effect of the neighbourhood environment across individual-level SEP. It is possible however that the socioeconomic context of the neighbourhood environment may affect people differently even if they have similar individual-level socioeconomic characteristics. For example, an individual with low educational attainment living in a more advantaged neighbourhood might have better physical function than an individual with the same educational attainment living in a more disadvantaged neighbourhood. This may be due to the benefit of the collective material and social resources in their neighbourhood, such as services, job opportunities and social supports [12, 94, 106].

This cross-sectional study investigates associations between neighbourhood disadvantage, individual-level SEP, and self-reported physical function; and further examines whether the relationship between individual-level SEP and physical function differs by level of neighbourhood disadvantage. It is hypothesised that those residing in more disadvantaged neighbourhoods and those from lower socioeconomic groups will exhibit poorer physical function than their counterparts from more advantaged backgrounds.

4.3 Methods

This study received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3967H & 1300000161).

4.3.1 Study population

Data were obtained from the How Areas in Brisbane Influence HealTh and AcTivity (HABITAT) multilevel longitudinal (2007–13) study in Brisbane, Australia. Brisbane is the capital city of the state of Queensland, and the third largest city in Australia with a population of approximately 2.3 million [281] and a median age of 35 in 2014 [213]. The average disposable income of Brisbane population was AU$52,000 per annum in 2011 [282].

Details about HABITAT's baseline sampling design have been published elsewhere.[217] Briefly, a multi-stage probability sampling design was used to select a stratified random sample (n=200) of CCD in 2007, and from within each CCD, a random sample of people (on average 85 per CCD) aged 40-65 years. However, as participants moved to new residences over time, the number of CCDs increased to 535 in 2013.

The primary area-level unit-of-analysis for the HABITAT study is the CCD (hereafter referred to as 'neighbourhoods'). At the time the study commenced in 2007, these were the smallest administrative units used by the ABS to collect census data, and contain an average of 200 private dwellings.

4.3.2 Data collection and response rate

A structured self-administered questionnaire was developed that asked respondents about their neighbourhood; participation in physical activity; correlates of activity, health and well-being; and socio-demographic characteristics. The questionnaire was sent to sampled residents during May-July in 2007, 2009, 2011 and 2013 using the mail survey method developed by Dillman [220]. After excluding out-of-scope respondents (i.e., deceased, no longer at the address, unable to participate for health-related reasons), the total number of usable surveys returned in each survey wave was 11,035 (68.3% response), 7,866 (72.3% response from eligible and contactable participants), 6,900 (66.7% response from eligible and contactable participants) and 6,520 (69.3% response from eligible and contactable participants), respectively.

4.3.3 Measures

Neighbourhood socioeconomic disadvantage

The neighbourhood socioeconomic disadvantage measure was derived using weighted linear regression, using scores from the ABS' IRSD from each of the previous six censuses from 1986 to 2011 [228]. A neighbourhood's IRSD score reflects each area's overall level of disadvantage measured on the basis of 17 socioeconomic attributes, including: education, occupation, income, unemployment, household structure and household tenure. HABITAT's original sample of neighbourhoods was stratified by area-level socioeconomic disadvantage using the 2001 Census boundaries (the Census in Australia is every 5 years). This method honours the original geographic structure from the baseline sample, while also accommodating for the changes in area boundaries used by the ABS prior to 2011, changes in area-level sampling units at the 2011 Census, and changes in socioeconomic disadvantage over time. The derived socioeconomic scores from each of the HABITAT neighbourhoods (n = 535 in 2013) were then grouped into quintiles based on their IRSD scores with Q1 denoting the 20% most advantaged areas relative to the whole of Brisbane and Q5 the most disadvantaged 20%.

Education

Respondents were asked to provide information about their highest education qualification completed using a nine-category measure that was subsequently coded as (i) Bachelor degree or higher (the latter included postgraduate diplomat, master's degree, or doctorate), (ii) Diploma (associate or undergraduate), (iii) Vocational (trade or business certificate or apprenticeship), and (iv) No post-secondary school qualification.

Occupation

Respondents who were employed at the time of completing the survey were asked to indicate their job title and then to describe the main tasks or duties they performed. This information was subsequently coded to the ASCO [256]. The ASCO is a skill-based measure that groups occupations according to levels of knowledge required, tools and equipment used, materials worked on, and goods and services produced. The occupational groupings are hierarchically ordered based on the relative skill levels across these different dimensions, with those occupations having the most extensive skill requirements located at the top of the hierarchy. For the purpose of this study, the original 9-level ASCO classification was recoded into 3 categories: (i) Managers/professionals, (ii) White collar employees, (iii) Blue collar employees. Respondents who were not employed were categorised as follows: (iv) Home duties, (v) Retired, (vi) Permanently unable to work, (vii) Missing/NEC (unemployed, students or other classifiable [not easily classifiable]).

Household income

Respondents were asked to indicate their total annual household income using a 14-category measure that was subsequently recoded into 6 groups for analysis: (i) AU$130,000 or more, (ii) AU$72,800–129,999, (iii) AU$41,600–72,799, (iv) AU$26,000–41,599, (v), Less than AU$25,999, and (vi) Missing/NEC.

Self-reported physical function

This was measured using the Physical Function Scale (PF-10), a component of the Short Form-36 (SF-36) Health survey [283]. The PF-10 was first included in the most recent wave of HABITAT survey (2013), so only cross-sectional analyses are possible at this point. The stem-question of the PF-10 asks: *'Does your health now limit you in these activities? If so, how much?'* Respondents were asked to indicate: *'Yes, limited a lot'* or '*yes, limited a little'* or *'no, not limited at al'* for each activity. The PF-10 measures a hierarchical range of difficulties, from vigorous activities such as lifting heavy objects to everyday activities such as bathing and dressing.[31] This measure has been extensively validated among community-dwelling adults using convergent validity calculated by Pearson Correlations using 3-performance based measures: single limb stance as an indicator of balance (r = 0.42), Time Up and Go test as a measure of mobility (r = -0.70) and gait speed as an indicator of overall functional capacity (r = 0.75)[25]. The method of data cleaning for the physical function score was adapted from Ware and colleagues [283]. The raw physical function scores were calculated as the sum of (re-coded) scale items and transformed to a 0 to 100 scale according to the Equation 1:

Equation 1:

$$Physical\ function\ score = \frac{raw\ score - minimum\ possible\ raw\ score}{possible\ raw\ score\ range}\ X\ 100$$

The standard scoring system was used such that 0 represents minimal functioning and 100 represents maximal functioning. The scale used for this present study obtained high test-retest reliability (Cronbach's α = 0.89) in the sample. Although scores were somewhat negatively skewed toward maximal function, they are comparable with Australian population norms for this scale (age standardised mean = 83.6 for men and 81.5 for women) [284].

4.3.4 Statistical analysis

Participants who moved out of Brisbane in 2013 (n = 391) or had missing data for physical function (n = 92), sex (n = 19) or education (n = 14) were excluded. This reduced the analytic sample to n = 6,004 (92.1% of the total sample). Characteristics and physical function profile of the analytic sample are presented in Table 4.1.

Table 4.1: Mean physical function (PF) scores (95% CI) for the socio-demographic variables used in the analysis[a]

	Men			Women		
N = 6,004	**N (%)**	**Mean PF score**	**95% CI**	**N (%)**	**Mean PF score**	**95% CI**
Total Sample	2,551	87.6	86.9, 88.3	3,453	83.7	83.0, 84.4
Age:						
46–50	571 (22.4)	92.2	91.0, 93.3	670 (19.4)	90.1	88.9, 91.3
51–55	551 (21.6)	88.9	87.6, 90.4	742 (21.5)	86.3	84.9, 87.7
56–60	520 (20.4)	86.8	85.3, 88.4	718 (20.8)	84.7	83.4, 86.0
61–65	488 (19.1)	85.5	83.8, 87.2	686 (19.9)	80.9	79.3, 82.5
66–71	421 (16.5)	83.2	81.4, 85.0	637 (18.4)	75.5	73.7, 77.3
Neighbourhood disadvantage						
Q1 (most advantaged)	543 (21.3)	91.8	90.7, 92.9	734 (21.3)	88.1	86.9, 89.2
Q2	680 (26.7)	90.0	88.9, 91.1	907 (26.3)	85.9	84.8, 87.1
Q3	516 (20.2)	87.3	85.8, 88.7	664 (19.2)	83.7	82.2, 85.2
Q4	466 (18.3)	85.3	83.6, 87.1	656 (19.0)	81.4	79.8, 82.9
Q5 (most disadvantaged)	346 (13.5)	80.1	77.5, 82.6	492 (14.2)	76.1	73.8, 78.4
Education level:						
Bachelor degree or higher	930 (36.5)	90.9	90.0, 91.8	1,156 (33.5)	86.8	85.7, 87.7
Diploma	312 (12.2)	89.4	87.9, 91.0	398 (11.5)	84.3	82.3, 85.7
Vocational	533 (20.9)	86.4	84.7, 88.1	499 (14.5)	84.0	82.3, 85.7
No post school qualifications	776 (30.4)	83.9	82.4, 85.3	1,400 (40.5)	80.9	79.8, 82.0
Occupation						
Manager/Professionals	928 (36.4)	91.7	90.9, 92.6	1,042 (30.2)	89.6	88.7, 90.5
White Collar	328 (12.9)	90.7	89.3, 92.1	870 (25.2)	86.9	85.8, 87.9
Blue Collar	485 (19.0)	88.1	86.6, 89.6	162 (4.7)	86.5	83.9, 89.1
Home Duties	18 (0.7)	83.3	71.8, 94.8	277 (8.0)	83.3	80.9, 85.7
Retired	510 (20.0)	82.7	81.1, 84.5	784 (22.7)	76.4	74.8, 78.0
Permanently unable to work	57 (2.2)	56.3	48.8, 63.8	62 (1.8)	38.5	30.9, 46.0
Missing/NEC	225 (8.8)	84.3	81.3, 87.3	256 (7.4)	80.2	77.6, 82.8
Household income:						
$130,000 or more	676 (26.5)	92.5	91.6, 93.4	589 (17.0)	90.9	89.8, 92.0
$72,800-129,999	631 (24.7)	89.8	88.7, 90.9	794 (23.0)	87.0	85.7, 88.1
$41,600-72,799	328 (12.9)	87.8	86.0, 89.5	398 (11.5)	84.1	82.2, 85.9
$26,000-41,599	438 (17.2)	83.6	81.8, 85.5	665 (19.3)	79.1	77.5, 80.7
Less than $25,999	216 (8.5)	73.6	70.0, 77.2	391 (11.3)	73.6	71.2, 76.0
Missing	262 (10.2)	87.7	85.5, 89.9	619 (17.9)	83.7	81.9, 85.3

[a] Unadjusted data

A DAG was constructed to show contextual and/or temporal relationships between the socioeconomic indicators education, occupation, household income, neighbourhood disadvantage, and physical function (Figure 4.1). The DAG formed the basis for the modelling strategy and specified the socioeconomic independent adjustment variables. As presented in Figure 1, education was conceptualized as a common prior cause of occupation, household income and neighbourhood disadvantage; occupation as a confounder of income and neighbourhood disadvantage, and household income as a confounder of neighbourhood disadvantage. The analyses were stratified by gender as physical function score differs for men and women (women consistently report more functional limitations than their men counterparts) [274, 285, 286].

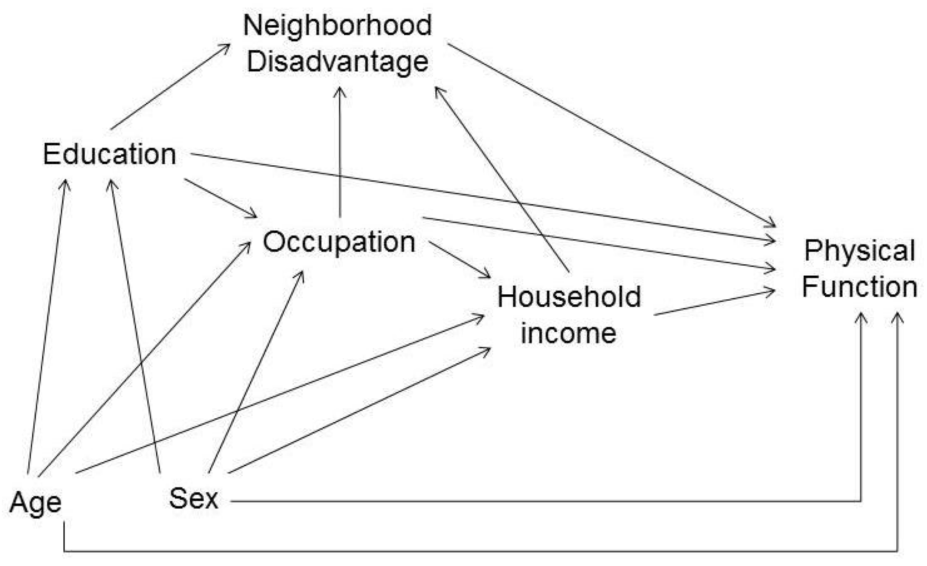

Figure 4.1: Directed acyclic graph conceptualising the relationships between neighbourhood disadvantage, individual-level socioeconomic position and physical function

Multilevel modelling is the appropriate statistical technique for these analyses as it offers a robust and efficient approach to the examination of hierarchical data where individuals are nested (clustered) within neighbourhoods [287]. Multilevel linear regression (MLLR) was undertaken in the following stages: Model 1) neighbourhood disadvantage and physical function adjusted for age; Model 2) neighbourhood disadvantage and physical function adjusted for age and individual-level SEP. Additional models were then undertaken for individual-level SEP; Model 3) education adjusted for age; Model 4) occupation adjusted for age and education; and Model 5) household income adjusted for age, education and occupation. The Variance Partition Coefficient (VPC) was calculated to estimate the percentage of total variance in physical function between neighbourhoods [264]. For Model 1 and 2, the VPC was calculated by dividing the between neighbourhood variance by the total variance, and is interpreted as the proportion of total residual variation that is due to differences between neighbourhoods. The analysis was extended to test for cross-level interactions by including interaction terms for different combinations of individual-level SEP and neighbourhood disadvantage on physical function score. The substantive focus of the interaction analyses is on whether associations between education, occupation, and household income differed across neighbourhoods that varied in their level of socioeconomic disadvantage. The fit of interaction models was assessed using a deviance test [288] (alpha set at 0.05). Models 1-5 were analysed with STATA 13.1 [267] using the *runMLwiN* command [289], while cross-level interaction models were analysed using MLwiN v.2.30 [288].

4.4 Results

The overall means for physical function score for neighbourhood disadvantage, age, education, occupation and household income are presented in Table 4.1. Mean physical function were lowest for women, persons aged 66–71, residents of the most disadvantaged neighbourhoods, the least educated, those who were permanently unable to work, and members of the lowest income households.

The associations between neighbourhood disadvantage, individual-level SEP and physical function for men and women are shown in Table 4.2.

Table 4.2: Multilevel linear regression for the association between neighbourhood disadvantage and individual-level socioeconomic position on physical function in men and women in Brisbane

N = 535 neighbourhoods	**Men (n = 2,551)**		**Women (n = 3,453)**	
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Neighbourhood-level				
Disadvantage	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Q1 (most advantaged)[a]	1.00	1.00	1.00	1.00
Q2	-1.89 (-3.89, 0.10)	-0.74 (-2.67, 1.18)	-1.92 (-3.78, -0.06)*	-1.57 (-3.38, 0.23)
Q3	-4.19 (-6.32, -2.06)***	-2.69 (-4.78, -0.60)*	-3.85 (-5.86, -1.84)***	-2.22 (-4.19, -0.23)*
Q4	-6.28 (-8.45, -4.11)***	-4.36 (-6.53, -2.19)***	-5.86 (-7.87, -3.85)***	-3.85 (-5.86, -1.83)***
Q5 (most disadvantaged)	-11.36 (-13.74, -8.99)***	-7.14 (-9.54, -4.73)***	-11.41 (-13.60, -9.22)***	-8.79 (-11.00, -6.59)***
Between neighbourhood variance (SE)[b]	1.79 (2.47)	1.33 (2.25)	0 (0)	0 (0)
Between individual variance (SE)[c]	285.36 (8.31)***	255.92 (7.71)***	358.97 (8.71)***	315.15 (7.65)***
VPC (%)[d]	0.62	0.53	0	0
Individual-level				
Education		**Model 3**		**Model 3**
Bachelor degree or higher[a]		1.00		1.00
Diploma		-0.88 (-3.08, 1.31)		-1.48 (-3.68, 0.71)
Vocational		-3.68 (-5.53, -1.84)*		-1.83 (-3.87, 0.21)
No post-school qualifications		-5.93 (-7.59, -4.27)**		-3.78 (-5.32, -2.25)*
Occupation		**Model 4**		**Model 4**
Manager/professional[a]		1.00		1.00
White collar		0.52 (-1.62, 2.66)		-1.39 (-3.19, 0.40)
Blue collar		-0.96 (-2.95, 1.03)		-1.22 (-4.33, 1.88)
Home duties		-7.04 (-14.65, 0.57)		-4.16 (-6.68, -1.63)***
Retired		-5.13 (-7.34, -2.93)*		-7.96 (-10.06, -5.85)***
Permanently unable to work		-32.21 (-36.68, -27.73)***		-48.99 (-53.79, -44.2)***
Household income:		**Model 5**		**Model 5**
$130,000+[a]		1.00		1.00
$72,800-129,999		-1.41 (-3.23, 0.41)		-2.98 (-4.89, -1.00)**
$41,600-72,799		-2.22 (-4.51, 0.06)		-3.56 (-5.93, -1.19)**
$26,000-41,599		-4.07 (-6.36, -1.78)**		-6.53 (-8.72, -4.33)***

Less than $25,999	-10.19 (-13.07, -7.30)***	-6.73 (-9.32, -4.13)***

Note. PF score range from 0-100; Statistical significance indicated by * p<0.05, ** p<0.01, *** p< 0.001; missing category is included in the analysis but not reported in the table. Model 1: age and neighbourhood disadvantage; Model 2: Model 1 and education, occupation and household income; Model 3: education and, age; Model 4: Model 3 and occupation; Model 5: Model 4 and household income.

[a] Reference group

[d] Variance Partition Component (VPC) = b/(b+c)

For men, there was no significant between-neighbourhood variation in physical function in either the age-adjusted (Model 1, $p = 0.48$) or fully-adjusted models (Model 2, $p = 0.56$). Men living in more disadvantaged neighbourhoods (Q3, Q4 and Q5) had lower physical function scores than their counterparts residing in more advantaged neighbourhoods. These associations remained significant after adjustment for individual-level SEP, despite slight attenuation. Compared to individuals with a bachelor degree or higher, individuals who had no post-school education, or a vocational level of education attainment had a significantly lower physical function score. Individuals who are retired and permanently unable to work had significantly lower physical function scores than managers and professionals, while individuals in the lower income categories ($26,000–41,599 and <$25,999) had significantly lower physical function than their counterparts with incomes of $130,000 or greater.

Similarly for women, there was no significant between-neighbourhood variation in physical function for either age-adjusted (Model 1) or fully-adjusted models (Model 2). Women living in more disadvantaged neighbourhoods (Q2, Q3, Q4 and Q5) had a significantly lower physical function score than their counterparts residing in more advantaged neighbourhoods. These associations remained significant after adjustment for individual-level SEP, despite slight attenuation. Compared to individuals with a bachelor degree or higher, individuals who had no post-school education had a significantly lower physical function score. Individuals working as home duties, retired and permanently unable to work had significantly lower physical function scores than managers and professionals, while individuals in the lower income categories ($72,800–129,999, $41,600–72,799, $26,000–41,599 and <$25999) had significantly lower physical function scores than their counterparts with incomes of $130,000 or greater.

Other than the significant results demonstrated, it is important to note the magnitude of difference in physical function score in men and women. A previous review found a three point difference in physical function score measured by SF-36 to be clinically meaningful for effective intervention [233]. Education attainment and household income appear to be more important, in terms of physical function, in men than women. Men with the lowest education attainment appear to have lower physical function scores (2 points) than women, after adjusting for age. Similarly, men with the lowest household income had physical function scores that were 4 points lower than low income women. On average, men and women who reported being permanently unable to work had very low physical function scores (<60), but the magnitude of difference between men and women in this group was notable. Women who reported being permanently unable to work, had, on average, a physical function score that was 17 points lower than men.

Cross-level interactions were not significant between neighbourhood disadvantage and education and occupation among men; and neighbourhood disadvantage and household income among women. However, a significantly better model fit was found between neighbourhood disadvantage and household income among men ($p = 0.004$); and neighbourhood disadvantage and education ($p = 0.01$) and occupation ($p < 0.001$) among women (Figure 4.2).

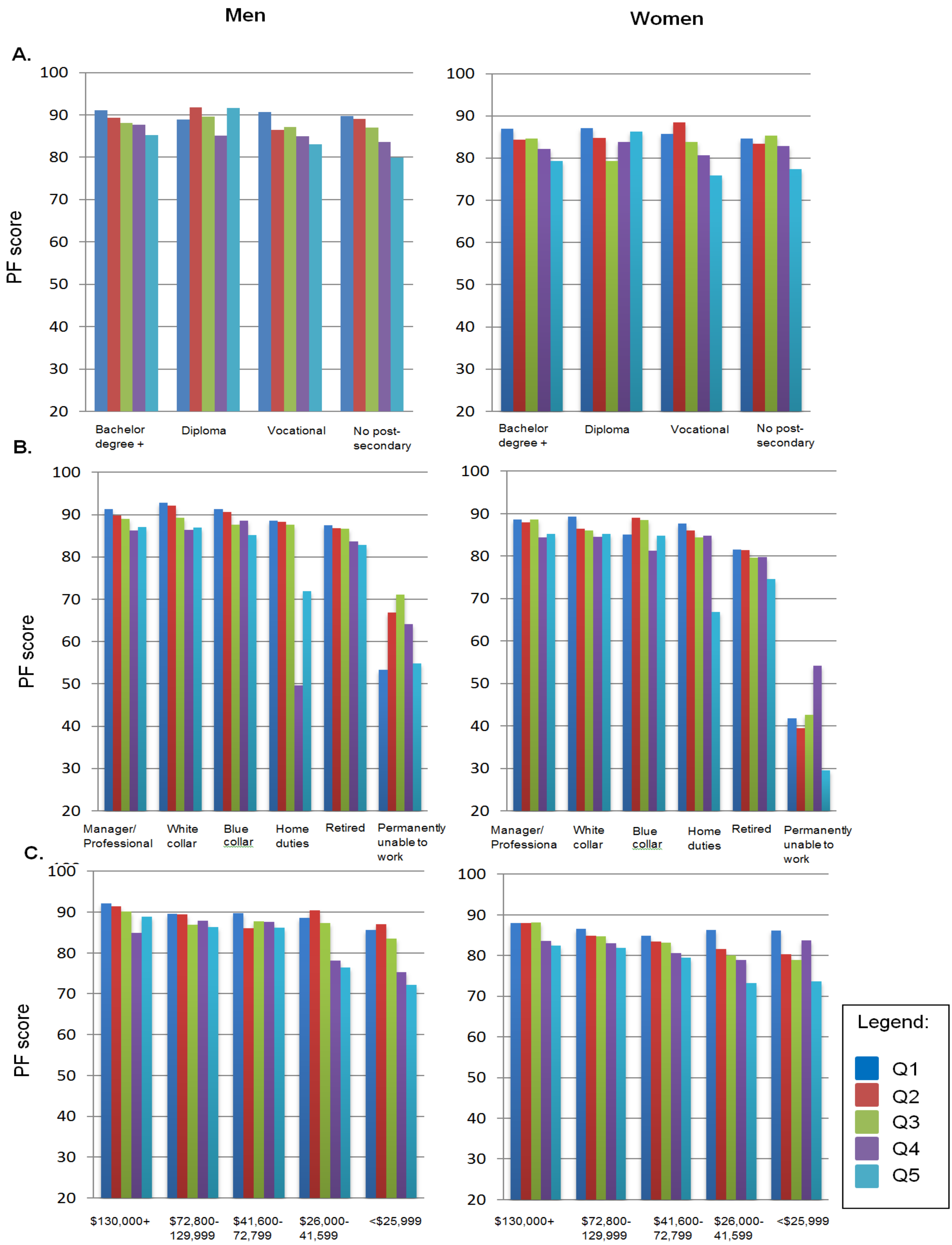

Figure 4.2: Cross-level interactions and mean physical function score between neighbourhood disadvantage and A. education, B. occupation and C. household income. Q1 – most advantaged and Q5 – most disadvantaged neighbourhoods

4.5 Discussion

This study examined associations between neighbourhood disadvantage, individual SEP and physical function. Significant and graded associations were found between neighbourhood disadvantage and physical function for both men and women, after adjusting for individual level SEP, suggesting that the socioeconomic characteristics of the neighbourhood environment may have important implications for physical function. The cross-level interaction models suggested that there was a protective effect of living in more socioeconomically advantaged neighbourhoods on physical function. The findings of this study are consistent with previous single-level studies conducted in the United States and the United Kingdom [119, 122], which found that individuals living in more disadvantaged neighbourhoods experienced poorer physical function than those in more advantaged neighbourhoods. However, the only previous multilevel study [120] from the United States found no association between neighbourhood disadvantage and physical function, after adjusting for individual-level factors. There are a number of possible explanations for the differences found between our study and those of Wight et al. [120]: including the sample age at the time at which data was collected, differences in the method of calculating area-level disadvantage, and geographical differences in the sampling of participants.

Consistent with prior research, men in our study were more likely to report better physical functioning than women [261, 290, 291]. The magnitude of difference in physical function score between men and women was notable in this study. Although this may due to the well-documented gender-based reporting bias on physical function [292], it is also possible that this discrepancy could be attributed to the differences in biology, control over resources and their decision making power in family and community, as well as the roles and responsibilities that society assigns to them [293].

Individuals in this study with higher levels of educational attainment, individuals with a higher level of occupation, and members of high income households reported higher physical function. Previous studies have shown that income and education are likely to be closely linked, but with one influencing the other via distinct aetiological pathways.[229, 294] Educational attainment for example, may influence the acquisition of knowledge about appropriate health practices, which may facilitate or constrain one's ability to maintain good physical function; whereas household income is likely to reflect the availability of resources to access health facilities and services [229, 295].

This investigation is the first-known study to examine cross-level interactions between neighbourhood disadvantage, individual level SEP and physical function. These models revealed that associations between individual socioeconomic indicators differed across levels of neighbourhood disadvantage. This finding brings to light interesting trends for how individuals with the same individual-level characteristics fared while residing in disadvantaged neighbourhoods, when compared with their counterparts in more advantaged neighbourhoods. For example, participants with the lowest education attainment living in the most disadvantaged neighbourhoods were observed to have the lowest physical function score, signifying double disadvantage. Double disadvantage has also been reported in other social epidemiological studies [296-298]. For instance, people with disability who live outside major cities may fare worse than their counterparts living in major cities, or people with no disability who live outside major cities [296]. These findings suggest that while individual- and neighbourhood-level socioeconomic disadvantage may affect physical function independently, they also interact with one another to impact physical function in a collective way. Therefore, living in a socioeconomically advantaged neighbourhood or having higher SEP attributes alone may not be enough to ensure better physical function.

The neighbourhood environment has emerged as an important context for health, by either facilitating healthy behaviour, or acting as a barrier [280]. A number of possible mechanisms may explain the significant associations found in our study. According to Ross and colleagues [156], the lack of economic and social resources in disadvantaged neighbourhoods predisposes residents to physical and social ailments due to limited opportunity, and lack of social integration and cohesion. Characteristics of disadvantaged neighbourhoods exist in both physical (e.g., lack of proper parks, health services, and tree coverage) and social forms (e.g., crime, public smoking or drinking, and conflicts). For example, one study [80] reported that neighbourhoods with multiple physical barriers such as poor access to public transport, inadequate lighting, trash and litter might trigger a pattern of disuse and subsequent decrements in functional health. On the other hand, neighbourhoods with an adverse social climate may discourage social ties between neighbours that may influence behaviour in ways that produce negative health outcomes [136, 137]. For example, neighbourhoods with greater social ties have higher levels of involvement in community activities, enabling residents to share ‘norms’ that influence health behaviours such as healthy eating and physical activity, both of which are important in the maintenance of physical function [103, 179]. Also, the physical and social characteristics that exist in disadvantaged neighbourhoods may influence physical function through different pathways such as physical activity [24, 32, 103], diet[30] and smoking [34, 299]. Several studies have suggested that particular neighbourhood features, including the presence of parks, recreational facilities, sidewalks and pleasant landscaping may promote physical activity among older adults [63, 300, 301]. While the lack of access to health food stores and the social norm of smoking in the neighbourhood are associated with poorer diet [302] and smoking behaviour [56], respectively. Therefore, living in a disadvantaged neighbourhood may not provide the environmental support for individual lifestyle behaviours that are needed to maintain good physical function.

Limitations

Several methodological and analytical issues need to be considered when interpreting and understanding this study's findings. First, the study is cross-sectional and thus claims about causality must be made with caveats. A longitudinal design would have added strength to the study findings. Second, the study data were obtained from the fourth wave of the HABITAT survey and sample attrition between baseline and 2013 may have implications for sample generalisability. The non-response rate in the HABITAT baseline study was 31.5%, and a comparison of the HABITAT baseline respondent sample with census data indicates an under-representation of men, those not in the workforce, those with low household income and those living in disadvantaged area [177]. Previous studies show that low SEP groups and residents of more deprived neighbourhoods are least likely to participate in survey research [303, 304]. As a result, the socioeconomic variation in the sample is likely to be less than that in the Brisbane population. Hence, it is likely that our results underestimate the 'true' magnitude of neighbourhood disadvantaged in physical function. Third, the findings of this study may also be confounded by unobserved individual and neighbourhood-level factors, such as social capital, or biased from the misclassification of self-reported responses. Fourth, the between neighbourhood variance for Models 1 and 2 in women was estimated as zero. Even though this 'null finding' suggests that neighbourhoods do not influence self-reports of physical function, this might be due to the study's statistical power to detect variance components [107]. In a multilevel analysis of neighbourhood effects, the power to detect variance components is influenced by the number of neighbourhoods sampled and the number of residents per neighbourhood. In examining this issue, Diez Roux [107] and Snijder et al. [305] suggest that even when variance estimates are very small, this does not mean that the data imply absolute certainty that the population value of the variance estimate is equal to zero, or that the effects of neighbourhood variables on individual-level outcomes are not worth investigating.

The findings from the current study can help to inform the development of policy-relevant interventions directed at both individual- and the neighbourhood-level contexts to delay the rate of physical function decline in ageing populations. Specifically, this study identified those residing in more disadvantaged neighbourhoods as having lower levels of physical function. This suggests that any targeted neighbourhood-level intervention should focus on neighbourhoods with greater levels of socioeconomic disadvantage. For example, smoking is associated with accelerated declines in physical function, [34] and previous work in Brisbane has shown that residents of more disadvantaged neighbourhood are more likely to smoke [56]. Interventions such as decreasing the number of tobacco outlets, especially in disadvantaged neighbourhoods, might contribute to a reduction of socioeconomic disparities in physical function. Establishing the mechanisms between neighbourhood disadvantage and physical function is crucial to the design of community-based interventions, as these processes are more amenable to change and more sustainable compared to changing individuals' behaviour that tend to be more challenging and short lived [306, 307]. This remains a priority for future research in this field.

4.6 Conclusion

Living in a disadvantaged neighbourhood was associated with poorer physical function, even after adjustment for individual-level factors. Future studies should explore the mechanisms that explain why residents of advantaged and disadvantaged neighbourhoods differ in their functional status.

CHAPTER 5: NEIGHBOURHOOD DISADVANTAGE AND PHYSICAL FUNCTION: IS THE RELATIONSHIP EXPLAINED BY NEIGHBOURHOOD PERCEPTIONS OF SAFETY FROM CRIME AND WALKING FOR RECREATION?

This chapter presents Study Two of the thesis, which extends the investigation undertaken in Study One by examining the role of neighbourhood perceptions of safety from crime and walking for recreation to the relationship between neighbourhood disadvantage and physical function. This chapter has been accepted for publication at Journal of Physical Activity and Health.

Citation:

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The nature and extend of contributions of authors for this publication are shown in Appendix I.

5.1 Abstract

Residents of socioeconomically disadvantaged neighbourhoods are more likely to report poorer physical function than their advantaged counterparts, although the reasons for this remain unknown. It is possible that neighbourhood-level perceptions of safety from crime (NPSC) contribute to this relationship through its association with walking for recreation. This study aimed to investigate if the relationship between neighbourhood disadvantage and physical function is explained by NPSC and walking for recreation. Data were obtained from the fourth wave (2013) of the HABITAT multilevel longitudinal study of mid-to-older aged adults (46 to 74 years) residing in 200 neighbourhoods in Brisbane, Australia. The data were analysed separately for men (n = 2149) and women (n = 2901) using multilevel models. Residents of the most disadvantaged neighbourhoods had poorer physical function, perceived their neighbourhoods to have higher crime and be less safe, and do less walking for recreation. These factors accounted for differences in physical function between disadvantaged and advantaged neighbourhoods (24% for men, 25% for women). This study highlights the importance of contextual characteristics, such as NPSC can have in explaining the relationship between neighbourhood disadvantage and physical function. Interventions aimed at improving neighbourhood safety integrated with supportive environments for physical activity, may have positive impact on physical function among all socioeconomic groups.

5.2 Introduction

Residents of socioeconomically disadvantaged neighbourhoods have significantly poorer physical function than their counterparts residing in more advantaged neighbourhoods [308]. Physical function is defined as one's ability to perform various activities that require physical capacity, ranging from activities of daily living to more vigorous activities that require an increasing degree of mobility, strength and endurance [25]. Physical function is therefore essential in performing many of the activities required for independent living [26]. From a policy perspective, it is important to know how and why neighbourhood disadvantage is associated with poorer physical function, as this knowledge may provide insights about which interventions might best contribute to reducing socioeconomic inequalities in health. At present however, current understanding of this relationship is at a nascent stage. In this study, we test the proposition that neighbourhood inequalities in physical function may be due in part to disadvantaged neighbourhoods having a social environment perceived by its residents as unsafe from crime, resulting in lower levels of walking for recreation (WfR) in these areas.

Consistent with the social ecological theory, individuals' health behaviours are partly influenced by the social environment in which they live [309], and studies have found that residents of disadvantaged neighbourhoods are more likely to perceive their social environment negatively, such as increased crime and disturbance from neighbours [117, 122, 310]. These negative perceptions are a likely barrier to outdoor physical activities such as walking, especially among women, who seem to be more sensitive to their neighbourhood environments [186, 311-314]. Walking is the most common physical activity among middle-aged Australians [180, 315], with recreational walking becoming more prevalent in post-retirement [316]. Notably, WfR is also most commonly undertaken within neighbourhood settings.[317] Living in a more disadvantaged neighbourhood is associated with lower levels of WfR [172, 318], and lower levels of walking are associated with poorer physical function [24, 210, 319].

The aim of this study is to examine the contribution of neighbourhood-level perceptions of safety from crime (NPSC) and WfR to the relationship between neighbourhood disadvantage and physical function. As previous studies have shown that relationships between neighbourhood environments and physical function are likely to be different for men and women [320], we stratified the analyses by gender. It is hypothesized that part of the association between neighbourhood disadvantage and physical function will be explained by differences in NPSC and WfR in advantaged and disadvantaged neighbourhoods. The findings may have implications for policy that aims to reduce neighbourhood-level inequalities in physical function among middle- to-older aged adults, offering one potential point of intervention: improving perceptions of safety from crime in disadvantaged neighbourhoods to support walking.

5.3 Methods

5.3.1 Study population

This investigation uses data from the HABITAT (How Areas in Brisbane Influence HealTh and AcTivity) study. HABITAT is a multilevel longitudinal study of mid-aged adults living in the Brisbane Local Government Area, Australia [321]. The primary aim of HABITAT is to examine patterns of change in health and well-being over the period 2007 – 2016, and to assess the relative contributions of environmental, social, psychological and socio-demographic factors to these changes. The HABITAT study received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3967H & 1300000161).

5.3.2 Sample Design

Details about HABITAT's baseline sampling design have been published elsewhere [217]. Briefly, a multi-stage probability sampling design was used to select a stratified random sample (n = 200) of CCD, and from within each CCD, a random sample of people aged 40–65 years (on average 85 per CCD). CCDs are embedded within a larger suburb, hence the area corresponding to, and immediately surrounding, a CCD is likely to have meaning and significance for their residents: for this reason, we hereafter use the term 'neighbourhood' to refer to each CCD. The baseline HABITAT sample (2007) was broadly representative of the wider Brisbane population, although residents from disadvantaged areas, blue collar employees, and those who did not attain a post-school educational qualification were underrepresented [321].

5.3.3 Data collection and response rates

A structured self-administered questionnaire was developed and copies were sent to 17,000 potentially eligible participants in May 2007 using a mail survey method developed by Dillman [220]. After excluding out-of-scope respondents (i.e., deceased, no longer at the last known address, unable to participate for health-related reasons), 11,035 usable surveys were returned yielding a baseline response rate of 68.3%: the corresponding response rates from in-scope and contactable participants in 2009, 2011, and 2013 were 72.6% (n = 7,866), 67.3% (n = 6,900), and 67.1% (n = 6,520) respectively.

5.3.4 Measures

Neighbourhood socioeconomic disadvantage

Each of the neighbourhoods was assigned a socioeconomic score using the ABS' IRSD [228]. A neighbourhood's IRSD score reflects each area's overall level of disadvantage measured on the basis of 17 variables that capture a wide range of socioeconomic attributes, including; education, occupation, income, unemployment, household structure, and household tenure (plus others). The derived socioeconomic scores from each of the HABITAT neighbourhoods were then grouped into quintiles based on their IRSD scores, with Q1 denoting the twenty-percent most advantaged areas relative to the whole of Brisbane and Q5 the most disadvantaged twenty-percent.

Neighbourhood-level perception of safety from crime

Participants were presented with six statements and asked to respond on a five-item Likert scale, ranging from 'strongly disagree' to 'strongly agree'. The statements asked participants about the level of crime in their neighbourhood, and perceptions of their personal safety in parks, on the streets, and using public transport in their area. The statements were adapted for the Australian population from the Neighbourhood Environment Walkability Scale (NEWS) questionnaire [322], which has acceptable validity and reliability for measuring the perceived neighbourhood walkability [222, 235]. PCA with Varimax rotation revealed that the six items loaded on one 'perceptions of crime and safety' factor, with a Cronbach alpha of 0.81. This factor was subsequently used in an EBE analysis to estimate NPSC. Rather than solely use a mean neighbourhood-level aggregated score, as has been done in previous studies [323-326], the EBE approach takes into account the number of participants in each neighbourhood, and the variability of the exposure within and between neighbourhoods [237]. Further details about the EBE approach to generating neighbourhood-level exposures can be found elsewhere [57, 101]. The 200 neighbourhoods were subsequently grouped into quintiles based on their ranked EBE score, with Q1 denoting the twenty-percent of neighbourhoods perceived as having low crime and being safe and Q5 denoting the twenty-percent of neighbourhoods perceived as having the most crime and being the least safe.

Neighbourhood self-selection

To assess residential attitudes, participants were asked to respond on a five-item Likert scale, ranging from ‘not at all important’ to ‘very important’ to 14 statements regarding ‘How important were the following reasons for choosing your current address?’ Examples of items included: ‘Ease of walking to places’, ‘Closeness to schools’, ‘Closeness to open spaces (e.g., parks)’ and ‘Closeness to public transport’. PCA with varimax rotation showed that 12 of the items loaded onto one factor, subsequently described as ‘neighbourhood self-selection’ (α = .84).

Walking for recreation

This was measured using a single question that asked respondents to report how much time (minutes) they had spent WfR in the previous week (i.e., recreation, leisure, or exercise). The distribution of the WfR variable was right-skewed and included outlier values which were top-coded to 840 minutes (equivalent to 2 hours walking each day) [223]. Level of WfR per week was categorised as none, low (1 to 149 minutes), and moderate to high ($\geq$ 150 minutes). The cut-point for the moderate to high category was consistent with the physical activity guidelines, which recommended at least 30 minutes of moderate activity, five days per week (equivalent to 150 minutes per week) [223].

Self-reported physical function

This was measured using the Physical Function Scale (PF-10), a component of the Short Form-36 (SF-36) Health Survey [283]. The stem question of the PF-10 asks: ‘Does your health now limit you in these activities? If so, how much?’ Respondents were asked to indicate: ‘Yes, limited a lot’ or ‘Yes, limited a little’ or ‘No, not limited at all’ for each activity. The PF-10 measures a hierarchical range of difficulties, from vigorous activities such as lifting heavy objects to bathing and dressing [327]. This measure has been extensively validated among community-dwelling adults using convergent validity calculated by Pearson Correlations using 3-performance based measures: single limb stance as an indicator of balance (r = 0.42), Time Up and Go test as a measure of mobility (r = −0.70) and gait speed as an indicator of overall physical functional capacity (r = 0.75) [25]. The method of data cleaning for the physical function score was adapted from Ware et al. [283]. The raw physical function scores were calculated as the sum of (re-coded) scale items and transformed to a 0 to 100 scale as follows:

$$Physical\ function\ score = \frac{raw\ score - minimum\ possible\ raw\ score}{possible\ raw\ score\ range}\ X\ 100$$

A standard scoring system was used such that 0 represents minimal functioning and 100 represents maximal functioning. The scale used for this present study obtained high test–retest reliability (Cronbach's α = 0.89) in the sample. Although scores were somewhat negatively skewed toward maximal function, they are comparable with Australian population norms for this scale (age standardised mean = 83.6 for men and 81.5 for women) [284].

Education

Respondents were asked to provide information about the highest education qualification completed. A respondent's education was subsequently coded as (i) Bachelor degree or higher (the latter included postgraduate diplomat, master's degree, or doctorate), (ii) Diploma (associate or undergraduate), (iii) Vocational (trade or business certificate or apprenticeship), and (iv) No post-secondary school qualification.

Occupation

Respondents who were employed at the time of completing the survey were asked to indicate their job title and then to describe the main tasks or duties they performed. This information was subsequently coded to the Australian Standard Classification of Occupations (ASCO). For the purpose of this study, the original ASCO classification was recoded into 3 categories: (i) Managers/professionals, (ii) White collar employees, (iii) Blue collar employees. Respondents who were not employed were categorised as follows: (iv) Home duties, (v) Retired, (vi) Permanently unable to work.

Household income

Respondents were asked to indicate their total annual household income (including pensions, allowances and investments) using a 14-category measure that was subsequently recoded into 6 groups for analysis: (i) AU$130,000 or more, (ii) AU$72,800-129,999, (iii) AU$41,600-72,799, (iv) AU$26,000-41,599, (v), Less than AU$25,999, and (vi) Not classified (i.e., ticked 'Don't know' or 'Don't want to answer this', or left the income question blank).

5.3.5 Statistical analyses

We excluded respondents who changed address after 2007 (n = 1,153) as moving to a different neighbourhood may have been be influenced by unmeasured preferences related to both residential choice and physical function [328]. Participants with missing data for physical function (n = 82), age (n = 1), WfR (n = 103) and education (n = 14) were also excluded. This reduced the analytic sample to n = 5,167. The number of participants across each of the 200 neighbourhoods ranged from 1-34 for men and 2-54 for women, and the mean (SD) per neighbourhood for men and women was 10.7 (6.7) and 14.5 (9.2) respectively. Analyses (not presented here) showed that those excluded due to missing data did not differ significantly from included respondents on neighbourhood disadvantage, sex, or physical function.

Decisions about the inclusion of variables and the modelling strategy were informed by the use of a DAG (Figure 5.1) which postulated relationships between neighbourhood socioeconomic disadvantage, NPCS, WfR, and physical function, adjusted for confounders: age, education, occupation, and household income. Consistent with previous research [308], analyses were stratified by gender as physical function scores differed for men and women.

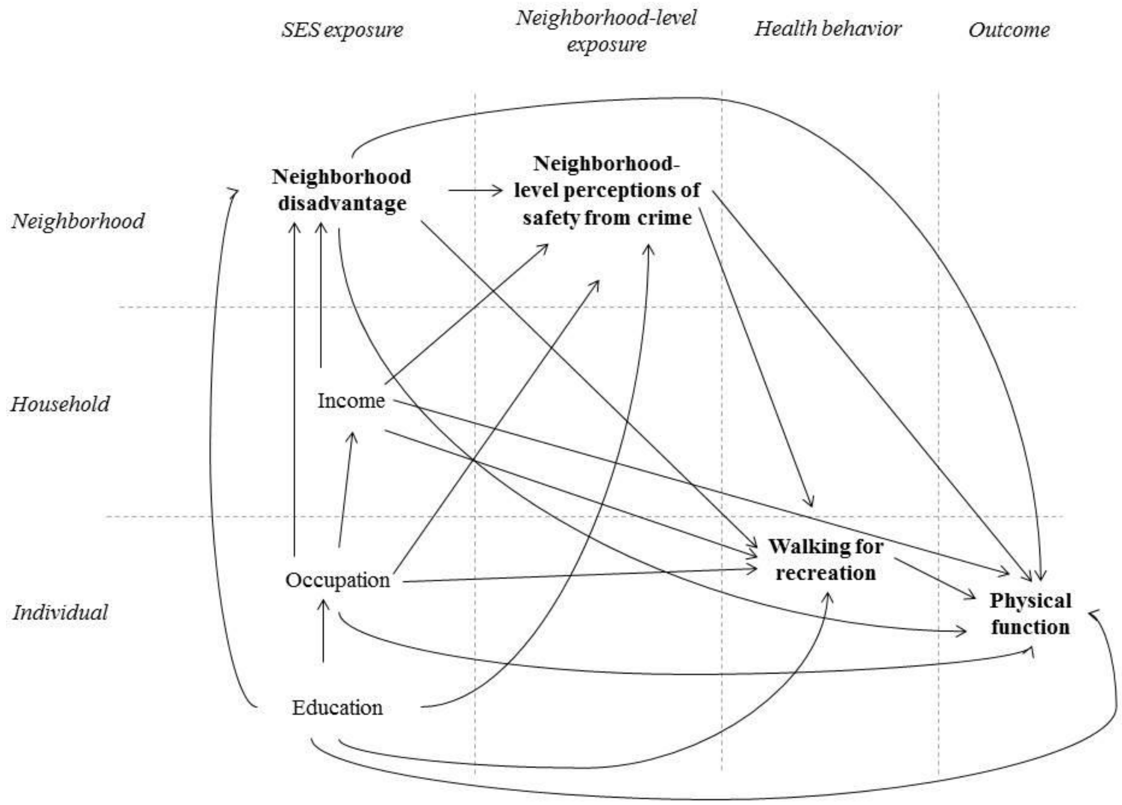

Figure 5.1: Directed acyclic graph conceptualising the relationship between neighbourhood disadvantage, neighbourhood-level perceptions of safety from crime, walking for recreation and physical function adjusted for age and sex

Multilevel modelling is the appropriate statistical technique for these analyses as it offers a robust and efficient approach to the examination of hierarchical data where individuals are nested (clustered) within neighbourhoods [285]. The analyses were conducted in seven stages. First, the relationship between neighbourhood disadvantage and physical function was examined using multilevel linear regression (MLLR), and the data were graphically presented as mean differences in physical function between the neighbourhood quintiles, adjusted for age and individual-level socioeconomic position (SEP). Second, we used an ecologic cross-tabulation to examine the neighbourhood-level relationship between socioeconomic disadvantage and perceptions of safety from crime: in particular, we focused on how advantaged and disadvantaged neighbourhoods were patterned (distributed) across the quintiles of NPSC. Third, the association between

NPSC and WfR was examined using multilevel multinomial logistic regression (MLMLR): Model 1 adjusted for age; Model 2 adds individual SEP and neighbourhood disadvantage. As recommended [265], the parameters for these models – odds ratios and 95% credible intervals – were estimated using Markov chain Monte Carlo simulation. This procedure was implemented using the Metropolis-Hastings algorithm with standard non-informative prior distributions on all parameters. To achieve convergence of the simulated chains for the variance parameters (assessed using the Raftery-Lewis and Brooks-Draper diagnostics) the Metropolis-Hastings algorithm was implemented for 50,000 iterations [265]. Fourth, the association between neighbourhood disadvantage and WfR was examined using MLMLR, using the same procedure as outlined in Stage three. Fifth, the association between NPSC and physical function was examined using MLLR: Model 1 presents mean differences in physical function across the quintiles of NPSC adjusted for age; and Model 2 adds individual SEP and neighbourhood disadvantage. Sixth, the association between WfR and physical function was examined using the same procedure as outlined in Stage five. Seventh, the contribution of NPSC and WfR to the association between neighbourhood disadvantage and physical function was examined using MLLR: Model 1 presents mean differences in physical function across the quintiles of neighbourhood disadvantage adjusted for age, education, occupation and household income; Model 2 adds NPSC; Model 3 adds WfR (excluding NPSC); and Model 4 adjusts for both NPSC and WfR. All data were prepared in STATA SE 13 [267] and the analyses were undertaken using MLwiN version 2.35 [266].

5.4 Results

Bivariate associations between physical function and neighbourhood disadvantage, respondents' sociodemographic characteristics, NPSC and WfR are presented in Table 5.1. Mean physical function scores were lowest among residents of disadvantaged neighbourhoods, the least educated, those who were permanently unable to work, members of low income households, and those in the oldest age group. Physical function scores were also lowest for those who strongly perceived their neighbourhood as being the least safe from crime, and those who did no WfR in the previous week.

Table 5.1: Socio-demographic characteristics and mean (95% confidence interval) physical function scores for the HABITAT analytic sample in 2013[a]

	Men (n = 2,190)		Women (n = 2,977)	
	%	Mean (95% CI)	%	Mean (95% CI)
Overall	42.3	87.7 (86.9, 88.4)	57.7	83.4 (82.7, 84.1)
Neighbourhood disadvantage				
Q1 (least disadvantaged)	20.9	91.8 (90.6, 92.8)	20.8	87.8 (86.5, 89.1)
Q2	27.1	90.2 (88.9, 91.3)	26.9	85.5 (84.3, 86.8)
Q3	20.5	87.5 (86.0, 89.0)	19.4	83.7 (82.1, 85.2)
Q3	18.4	85.3 (83.4, 87.1)	19.1	80.8 (79.2, 82.5)
Q5 (most disadvantaged)	13.1	79.9 (77.1, 82.6)	13.8	75.7 (73.2, 78.2)
Age				
45-49 years	20.9	92.3 (91.1, 93.5)	18.9	89.7 (88.4, 91.1)
50-54 years	21.9	89.3 (87.8, 90.7)	21.9	86.4 (85.0, 87.9)
55-59 years	20.5	87.0 (85.4, 88.6)	20.2	84.5 (83.0, 85.9)
60-65 years	19.4	85.8 (84.0, 87.6)	20.5	80.7 (79.0, 82.3)
66+ years	17.3	83.2 (81.2, 85.1)	18.5	75.1 (73.2, 77.1)
Education				
Bachelor degree or higher	36.2	91.1 (90.2, 92.0)	33.6	86.6 (85.6, 87.7)
Diploma/associate degree	12.4	89.4 (87.7, 91.1)	11.5	83.8 (81.7, 85.9)
Certificate	21.1	86.5 (84.7, 88.3)	14.2	83.8 (81.9, 85.6)
No post-school qualification	30.2	83.8 (82.3, 85.4)	40.7	80.5 (79.2, 87.7)
Occupation				
Professional	36.1	91.7 (90.9, 92.6)	29.5	89.4 (88.4, 90.3)
White collar	13.0	91.0 (89.7, 92.4)	25.2	86.5 (85.3, 87.7)
Blue collar	19.0	88.1 (86.5, 89.7)	4.8	85.7 (82.7, 88.7)
Home duties	0.7	81.2 (68.7, 93.8)	8.2	83.8 (81.2, 86.2)
Retired	20.4	82.9 (81.1, 84.7)	23.6	76.3 (74.6, 77.9)
Permanently unable to work	2.4	57.1 (49.4, 64.8)	1.8	38.1 (30.4, 45.8)
Not easily classifiable[b]	8.4	85.3 (82.2, 88.3)	6.8	80.7 (77.9, 83.5)
Income				
$130,000+	25.7	92.9 (92.0, 93.8)	16.7	90.7 (89.5, 91.9)
$72,800-129,999	24.8	89.6 (88.4, 90.8)	22.6	86.7 (85.4, 88.0)
$52,000-72,999	13.0	87.8 (85.9, 89.6)	11.8	84.1 (82.2, 86.1)
$26,000-51,999	18.0	83.8 (81.9, 85.7)	19.2	78.5 (76.8, 80.3)
Less than $25,999	8.4	74.8 (71.1, 78.4)	11.8	73.5 (70.9, 76.0)
Not classified[c]	10.1	87.4 (84.9, 89.8)	17.9	83.6 (81.8, 85.4)
Neighbourhood-level perceptions of safety from crime[d]				
Q1 (0-25.0)	20.0	83.8 (81.9, 85.7)	19.9	79.3 (77.4, 81.2)
Q2 (25.1-33.2)	19.7	84.9 (83.0, 86.7)	18.8	81.2 (79.5, 82.9)
Q3 (33.3-39.4)	20.2	88.3 (86.8, 89.9)	21.0	82.6 (80.9, 84.2)
Q4 (39.5-50.6)	20.0	90.4 (88.9, 91.7)	19.5	85.5 (84.1, 86.9)
Q5 (50.7-100)	20.1	91.1 (89.9, 92.3)	20.8	88.1 (86.8, 89.3)
Walking for recreation in the previous week (minutes)				
Moderate to high (≥150 Min.)	30.7	88.8 (87.6, 89.9)	34.4	87.5 (86.6, 88.6)
Low (1-149 Min.)	35.0	89.4 (88.3, 90.4)	35.3	84.9 (83.9, 86.0)
None (0 Min.)	34.3	85.0 (83.6, 86.5)	30.3	76.8 (75.3, 78.4)

[a]Physical function score ranged from 0-100, where 0 represents minimal functioning and 100 represents maximal functioning. [b]Not easily classifiable: students, unemployed or other classifiable. [c]Not classified: those who reported 'Don't know' or 'Don't want to answer this', or left the income question blank. [d] [d]Neighbourhood-level perceptions of safety from crime score ranged from 0-100, Q1 represents neighbourhoods perceived as the least safe from crime, Q5 represents neighbourhoods perceived as the safest from crime.

Neighbourhood disadvantage and physical function

After adjusting for age and individual-level SEP, there was a significant graded association between neighbourhood disadvantage and physical function for both men and women (Figure 5.2). Residents from more disadvantaged neighbourhoods (Q4 and Q5) had significantly lower physical function scores than their counterparts from more advantaged neighbourhoods (Q1 and Q2).

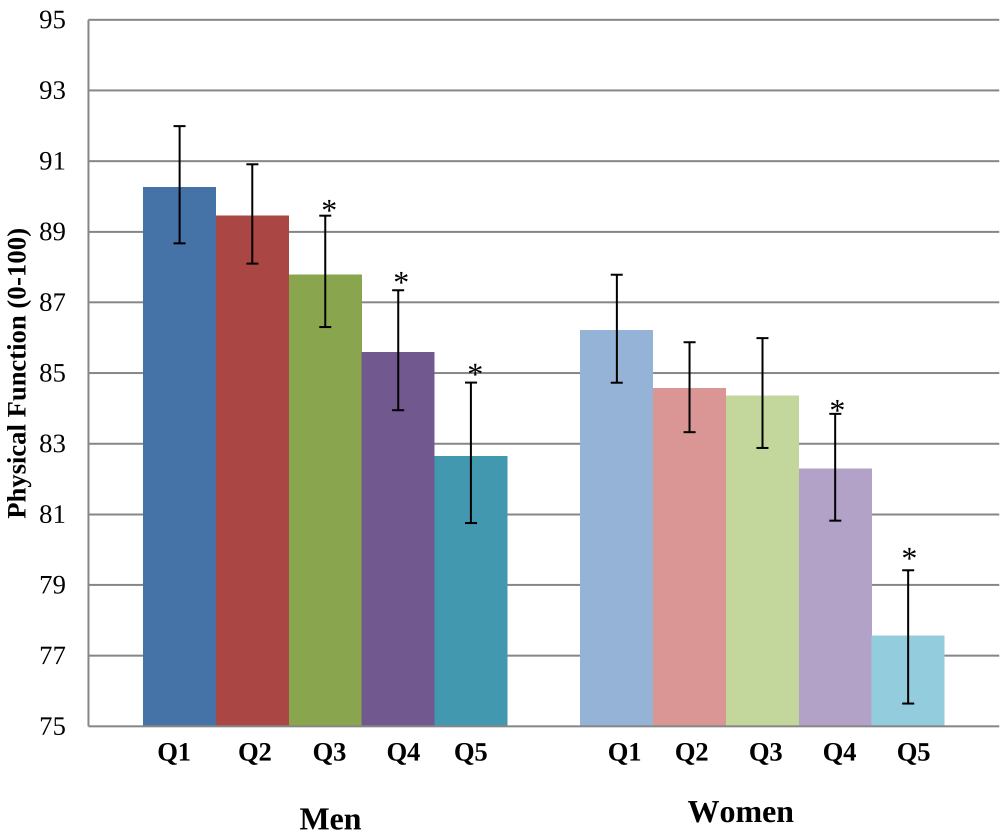

Figure 5.2: Relationship between neighbourhood disadvantage and physical function (0-100) for men and women. Model adjusted for within-neighbourhood variation in age, education, occupation, household income and neighbourhood self-selection. Q1 represents the most advantaged neighbourhood and is also the reference group. * indicates significance at $p < 0.001$

Neighbourhood disadvantage and neighbourhood-level perceptions of safety from crime

The data in Table 5.2 show that more disadvantaged neighbourhoods were perceived as having lower levels of safety from crime than more advantaged neighbourhoods. Among men, for example, 30% (n = 12) of the most disadvantaged neighbourhoods were categorised in the lowest quintile of NPSC, compared with 2.5% (n = 1) of the least disadvantaged neighbourhoods: the corresponding percentages for women were 52.5% (n = 21) and 7.5% (n = 3).

Table 5.2: Association between neighbourhood disadvantage and neighbourhood-level perceptions of safety from crime for men and women

N = 200 neighbourhoods **Neighbourhood disadvantage**	**Neighbourhood-level perceptions of safety from crime**[a]					
	Q1 %	**Q2 %**	**Q3 %**	**Q4 %**	**Q5 %**	**Total N**
Men						
Q1 (least disadvantaged)	2.5	10.0	17.5	27.5	42.5	40
Q2	0.0	15.0	22.5	27.5	35.0	40
Q3	15.0	25.0	22.5	20.0	17.5	40
Q4	22.5	30.0	30.0	17.5	0.0	40
Q5 (most disadvantaged)	30.0	20.0	7.5	7.5	5.0	40
Women						
Q1 (least disadvantaged)	7.5	5.0	15.0	25.0	47.5	40
Q2	0.0	20.0	22.5	30.0	27.5	40
Q3	12.5	17.5	25.0	25.0	20.0	40
Q4	27.5	32.5	20.0	20.0	0.0	40
Q5 (most disadvantaged)	52.5	25.0	17.5	0.0	5.0	40

[a]Neighbourhood-level perceptions of safety from crime, where Q1 represents neighbourhoods perceived as the least safe from crime, Q5 represents neighbourhoods perceived as the safest from crime.

Neighbourhood-level perceptions of safety from crime and walking for recreation

Among men, the age-adjusted odds of WfR at low levels were significantly higher among those living in neighbourhoods that were perceived as being the safest from crime (Table 5.3). However, after further adjustment for individual-level SEP and neighbourhood disadvantage, the association attenuated to the null. Among women, the age-adjusted odds of WfR at low and moderate to high levels were significantly greater for those living in neighbourhoods perceived as safer from crime than those living in neighbourhoods perceived as the least safe from crime. While the association attenuated after adjustment for individual-level SEP and neighbourhood disadvantage (Model 2), the odds of WfR at moderate to high levels remained significant for women living in neighbourhoods that were perceived as the safest from crime (Q1;Table 5.3).

Neighbourhood disadvantage and walking for recreation

Among men, the age-adjusted odds of WfR at low and moderate to high levels were significantly greater in less disadvantaged neighbourhoods than in the most disadvantaged neighbourhoods (Table 5.3); however, after further adjustment for individual-level SEP, none of the associations reached statistical significance. Among women, the odds of WfR at low and moderate to high levels were significantly higher in less disadvantaged neighbourhoods than the most disadvantaged neighbourhoods, before and after adjustment for individual-level SEP (Table 5.3).

Table 5.3: Associations between neighbourhood-level perceptions of safety from crime, neighbourhood disadvantage and walking for recreation for men and women (odds ratio and 95% credible intervals)

N = 200 neighbourhoods Neighbourhood-level perceptions of safety from crime	Walking for recreation in the previous week (minutes)					
	Model 1[a]			Model 2[b]		
	None (0 Min.)	Low (1-149 Min.) OR (95% CrI)	Moderate to high (≥150 Min.) OR (95% CrI)	None (0 Min.)	Low (1-149 Min.) OR (95% CrI)	Moderate to high (≥150 Min.) OR (95% CrI)
Men (n = 2,190)						
Q1 (least safe from crime)	1.00	1.00	1.00	1.00	1.00	1.00
Q2	1.00	1.05 (0.73, 1.51)	1.21 (0.84, 1.76)	1.00	0.92 (0.65, 1.30)	1.13 (0.78, 1.63)
Q3	1.00	1.01(0.72, 1.44)	1.02 (0.71, 1.49)	1.00	0.79 (0.55, 1.14)	0.88 (0.61, 1.30)
Q4	1.00	1.41 (0.99, 2.01)	1.42 (0.98, 2.07)	1.00	1.02 (0.70, 1.51)	1.21 (0.81, 1.82)
Q5 (safest from crime)	1.00	1.42 (1.01, 2.03)*	1.41 (0.97, 2.05)	1.00	1.03 (0.69, 1.54)	1.23 (0.80, 1.87)
Women (n = 2,977)						
Q1 (least safe from crime)	1.00	1.00	1.00	1.00	1.00	1.00
Q2	1.00	0.84 (0.60, 1.17)	0.89 (0.63, 1.26)	1.00	0.73 (0.54, 0.99)*	0.85 (0.62, 1.15)
Q3	1.00	1.03 (0.74, 1.42)	1.19 (0.85, 1.67)	1.00	0.84 (0.61, 1.15)	1.06 (0.76, 1.46)
Q4	1.00	1.23 (0.87, 1.71)	1.61 (1.13, 2.28)*	1.00	0.97 (0.69, 1.35)	1.47 (1.03, 2.11)*
Q5 (safest from crime)	1.00	1.41 (1.01, 1.99)*	2.02 (1.43, 2.89)**	1.00	1.00 (0.68, 1.46)	1.70 (1.14, 2.51)*
Neighbourhood disadvantage						
Men (n = 2,190)						
Q5 (most disadvantaged)	1.00	1.00	1.00	1.00	1.00	1.00
Q4	1.00	1.24 (0.82, 1.86)	1.13 (0.75, 1.72)	1.00	1.16 (0.80, 1.68)	1.19 (0.80, 1.77)
Q3	1.00	1.34 (0.89, 1.99)	1.26 (0.82, 1.91)	1.00	1.28 (0.88, 1.84)	1.37 (0.93, 2.03)
Q2	1.00	1.51 (1.02, 2.79)*	1.37 (0.92, 2.05)	1.00	1.35 (0.94, 1.93)	1.41 (0.97, 2.06)
Q1 (least disadvantaged)	1.00	1.13 (0.75, 1.71)	1.59 (1.04, 2.41)*	1.00	1.58 (1.07, 2.31)*	1.60 (1.05, 2.40)*
Women (n = 2,977)						
Q5 (most disadvantaged)	1.00	1.00	1.00	1.00	1.00	1.00
Q4	1.00	1.27 (0.88, 1.82)	1.28 (0.87, 1.87)	1.00	1.23 (0.90, 1.69)	1.20 (0.87, 1.68)
Q3	1.00	1.49 (1.03, 2.14)*	1.42 (0.97, 2.08)*	1.00	1.40 (1.02, 1.93)*	1.37 (0.99, 1.91)
Q2	1.00	1.46 (1.04, 2.09)*	1.51 (1.06, 2.16)*	1.00	1.34 (0.99, 1.82)	1.51 (1.10, 2.08)*
Q1 (least disadvantaged)	1.00	1.83 (1.28, 2.62)**	2.06 (1.40, 3.03)***	1.00	1.50 (1.07, 2.07)*	1.76 (1.26, 2.45)**

Notes: Statistical significance indicated by *p<0.05, ** p<0.01, ***p<0.001. Abbreviations: OR, odds ratio; CrI, credible intervals.
[a]Model adjusted for age. [b]Model 1 plus adjustment for education, occupation, household income, neighbourhood disadvantage and neighbourhood self-selection.

Neighbourhood-level perceptions of safety from crime and physical function

After adjusting for age (Model 1), living in a neighbourhood perceived as being less safe from crime (Q1, Q2 and Q3) was associated with lower physical function scores for both men and women (Table 5.4). These associations were attenuated after further adjustment for individual-level SEP and neighbourhood disadvantage, and remained statistically significant only for women (Model 2).

Table 5.4: Associations between neighbourhood-level perceptions of safety from crime, walking for recreation and physical function in men and women (β coefficient and 95% confidence intervals)

N = 200 neighbourhoods	**Physical function[a]**	
Neighbourhood-level perceptions of safety from crime	**Model 1[b] β (95% CI)**	**Model 2[c] β (95% CI)**
Men (n = 2,190)		
Q5 (safest from crime)	-	-
Q4	-0.73 (-3.40, 1.94)	0.31 (-1.94, 2.56)
Q3	-2.82 (-5.47, -0.18)*	-0.46 (-2.83, 1.90)
Q2	-6.39 (-9.02, -3.77)***	-2.08 (-4.53, 0.18)
Q1 (least safe from crime)	-7.45 (-10.07, -4.82)***	-1.50 (-4.20, 1.19)
Women (n = 2,977)		
Q5 (safest from crime)	-	-
Q4	-2.46 (-4.74, -0.19)*	-0.84 (-3.16, 1.47)
Q3	-5.04 (-7.27, -2.81)***	-2.92 (-5.14, -0.69)*
Q2	-6.32 (-8.61, -4.02)***	-3.02 (-5.52, -0.53)*
Q1 (least safe from crime)	-8.26 (-10.52, -5.99)***	-1.95 (-4.58, 0.66)
Walking for recreation		
Men (n = 2,190)		
None (0 Min.)	-	-
Low (1-149 Min.)	4.06 (2.39, 5.74)***	3.00 (1.36, 4.62)***
Moderate to high (>150 Min.)	4.21 (2.47, 5.98)***	4.12 (2.48, 5.77)***
Women (n = 2,977)		
None (0 Min.)	-	-
Low (1-149 Min.)	7.37 (5.69, 9.05)***	5.62 (4.02, 7.22)***
Moderate to high (>150 Min.)	10.54 (8.84, 12.23)***	9.24 (7.63, 10.84)***

Notes: Statistical significance indicated by *p<0.05, **p<0.01, ***p<0.001. Abbreviations: β, beta coefficient; CI, confidence interval.
[a]Physical function score ranged from 0-100, where 0 represents minimal functioning and 100 represents maximal functioning. [b]Model adjusted for age. [c] Model 1 plus adjustment for education, occupation, household income, neighbourhood disadvantage and neighbourhood self-selection.

Walking for recreation and physical function

WfR was positively associated with physical function for both men and women before and after adjustment for individual-level SEP and neighbourhood disadvantage (Table 5.4). Men who walked for 150 minutes or more in the previous week had a mean physical function score approximately four points higher than those who reported no walking: the corresponding mean difference for women was approximately 10 points.

Neighbourhood disadvantage and physical function adjusting for neighbourhood-level perceptions of safety from crime and walking for recreation

Men and women residing in the most disadvantaged neighbourhoods had a significantly lower physical function score than their counterparts living in the least disadvantaged neighbourhoods (Table 5.5). These associations remained significant after adjustment for NPSC, but attenuated by 20% for men and 18% for women. After adjusting for WfR, these associations remained significant, but attenuated by 5% for men and 10% for women. After simultaneous adjustment for NPSC and WfR, these associations were further attenuated. These factors accounted for 25% and 21% of the association between neighbourhood disadvantage and physical function conditioned upon age, individual-level SEP and neighbourhood self-selection for men and women respectively; although in both men and women, physical function scores remained significantly lower for residents of the most disadvantaged neighbourhoods.

Table 5.5: Relationship between neighbourhood disadvantage and physical function adjusting for individual-level socioeconomic position (Model 1), neighbourhood-level perceptions of safety from crime (Model 2), recreation walking (Model 3) and the fully adjusted model (Model 4)

Neighbourhood disadvantage	**Physical function[a]**			
	Model 1[b] **β (95%CI)**	**Model 2[c]** **β (95%CI)**	**Model 3[d]** **β (95%CI)**	**Model 4[e]** **β (95%CI)**
Men (n = 2,190)				
Q1 (least disadvantage)	-	-	-	-
Q2	-0.53 (-2.60, 1.53)	-0.24 (-2.36, 1.87)	-0.44 (-2.51, 1.63)	-0.20 (-2.31, 1.91)
Q3	-2.32 (-4.58, -0.7)*	-1.61 (-4.01, 0.78)	-2.21 (-4.47, 0.04)	-1.55 (-3.95, 0.84)
Q4	-4.24 (-6.60, -1.89)***	-3.38 (-5.97, -0.81)**	-4.04 (-6.40, -1.69)***	-3.26 (-5.84, -0.68)**
Q5 (most disadvantaged)	-6.48 (-9.12, -3.85)***	-5.17 (-8.27, -2.07)***	-6.14 (-8.77, -3.51)***	-4.88 (-7.98, -1.78)**
Women (n = 2,977)				
Q1 (least disadvantaged)	-	-	-	-
Q2	-1.52 (-3.44, 0.39)	-0.79 (-2.85, 1.27)	-1.32 (-3.20, 0.55)	-0.79 (-2.81, 1.22)
Q3	-1.98 (-4.10, 0.12)	-1.07 (-3.46, 1.31)	-1.67 (-3.74, 0.39)	-1.04 (-3.38, 1.29)
Q4	-3.36 (-5.54, -1.196**	-1.92 (-4.49, 0.65)	-2.86 (-4.99, -0.73)**	-1.91 (-4.43, 0.61)
Q5 (most disadvantaged)	-7.88 (-10.25, -5.50)***	-6.48 (-9.35, -3.62)***	-7.13 (-9.46, -4.81)***	-6.26 (-9.06, -3.45)***

Notes: Statistical significance indicated by *p<0.05, ** p<0.01, *** p<0.001. Abbreviations: β, beta coefficient; CI, confidence intervals
[a]Physical function score ranged from 0-100, where 0 represents minimal functioning and 100 represents maximal functioning. [b]Model 1: adjusted for age, education, occupation, household income and neighbourhood self-selection. [c] Model 2: Model 1 plus adjustment for neighbourhood-level perceptions of safety from crime. [d] Model 3: Model 1 plus adjustment for walking for recreation. [e]Model 4: Model 1 plus adjustment for walking for recreation. [e]Model 1 plus adjustment for neighbourhood-level perceptions of safety from crime and walking for recreation

5.5 Discussion

This study found that living in more socioeconomically disadvantaged neighbourhoods was significantly associated with poorer physical function, which is consistent with previous research [113, 116, 119, 122, 308]. In an effort to move beyond the descriptive nature of previous studies and explore possible mechanistic pathways, we examined the contribution of NPSC and WfR to this relationship. Residents of more disadvantaged neighbourhoods perceived their neighbourhoods to be less safe from crime; and women in these neighbourhoods did less WfR than those in advantaged neighbourhoods. These two factors partly attributed for the observed differences in physical function between disadvantaged and advantaged neighbourhoods.

Our finding that residents of more disadvantaged neighbourhoods reported lower levels of NPSC is consistent with previous research [117, 122, 310]. For example, a study in London [117] found that participants living in more disadvantaged neighbourhoods were more likely to report negative social features such as crime, disturbance by neighbours and vandalism. This finding is important, because lower perceptions of safety from crime within neighbourhoods have previously been shown to have implications for walking behaviours. A systematic review [311] reported that high levels of neighbourhood crime were a barrier to walking in the neighbourhood: this effect was found to be stronger among women and older adults [329]. We found greater levels of WfR among residents of neighbourhoods with higher perceptions of safety from crime, but this relationship was only statistically significant among women. The gender difference in the relationship between NPSC on both physical function and WfR could be explained by research indicating that women are more ‘ecologically vulnerable’ than men, and more sensitive to their immediate surroundings [42, 330]. Mark [331] for example, found an interaction between gender and risk, where equal exposure to risk resulted in greater fear among women than men. Men, on the other hand, were found to have lower levels of fear, and often perceived themselves as invulnerable, leading them to discount risk. In our study, gender-specific findings were also observed in the relationship between neighbourhood disadvantage and WfR; after adjusting for age and individual-level SEP, the association remained for women only. The gender differences observed in this study highlight the importance of conducting analyses separately for men and women, to improve understanding of the effects of NPSC on WfR and physical function.

Consistent with other studies using self-report measures of crime [80, 139-143], we found a significant association between NPSC and physical function. However, after adjusting for individual- and neighbourhood-level socioeconomic factors, the association remained only among women. Despite evidence that physical function differs for men and women, and the social aspects of the neighbourhood environment have larger effects for women than men, only one study [113] stratified data by gender, and found negligible differences for men and women. The results from our study however, and those of Freedman et al. [113], may not be comparable, due to differences in the measure used to assess safety from crime (self-report vs objective), and the different country contexts (Australia vs US). Further, it is well-established that participation in regular, moderate physical activity (including walking) is beneficial for physical function [26, 210, 319, 332]. The relative risk of older adults losing functional independence may be reduced by up to 30% through engagement in 150-180 minutes per week of moderate to vigorous physical activity, such as brisk walking [210]. Our results showed that WfR was positively associated with physical function, and previous longitudinal analyses have shown that moderate intensity activity, such as walking, prevents functional decline [205].

Bringing together the pathways tested in the current study, both NPSC and WfR explained part of the relationship between neighbourhood disadvantage and physical function for men and women. NPCS however, explained a larger part of this relationship: 20% and 21% for men and women, compared with 4% for men and10% for women explained by WfR. A similar study by Feldman and Steptoe [122] in London found that residents living in more disadvantaged neighbourhoods perceived greater neighbourhood strain (measured by levels of social cohesion, neighbourhood problems, and vigilance for threat), that in turn, was associated with poorer physical functioning. To the best of our knowledge, few studies have examined the mechanistic pathways between neighbourhood disadvantage and physical function. Our findings and those of Feldman and Steptoe [122] suggest that the relationships between neighbourhood disadvantage, NPSC, WfR and physical function are complex and at present, not well understood. Nevertheless, the current study makes an important contribution to advancing understanding of why residents of more disadvantaged neighbourhoods have poorer physical function: it seems in part because they are more concerned about safety from crime in their local environment and hence, they are less likely to walk for recreation. Although other factors are likely to contribute to the relationship between neighbourhood disadvantage and physical function, our study adds to the nascent understanding of potential mechanisms.

Limitations

This study has a number of limitations. First, the cross-sectional design means that claims about causality must be made with caveats, as it is plausible that poor physical function could negatively impact on WfR. Examining change over time in neighbourhood disadvantage, NPSC, WfR and physical function would add strength to the study findings. Further, examining these relationships in the context of residential mobility over time (allowing for large changes in neighbourhood exposures), and analysis of within-individual changes, would have provided stronger evidence for causal claims [333]. Second, the study data were obtained from the fourth wave of the HABITAT survey, and sample attrition at both baseline and between baseline and the fourth wave may have implications for generalizability. The non-response rate in the HABITAT baseline study was 31.5%, and a comparison of the HABITAT baseline sample with census data indicates an under-representation of men, those not in the workforce, those with low household income and those living in disadvantaged areas [177]. Previous studies show that low SEP groups and residents of more deprived neighbourhoods are least likely to participate in survey research [303, 304]. As a result, the socioeconomic variation in the sample is likely to be less than that in the Brisbane population. Therefore, it is likely that the findings of this study underestimate the true magnitude of the relationships examined. Third, data on WfR, NPSC and physical function were self-reported and therefore subject to recall bias [334, 335]. Fourth, the WfR survey item did not specify the setting in which the walking activity was undertaken. It is possible that the reported walking duration was undertaken outside of participants' neighbourhoods. In addition, the walking item in the survey was unable to capture the intensity of walking, which has shown to be more important for health than the total walking time [193]. Objective measures, such as those derived using accelerometers, would have overcome this limitation.

This study highlights the potential importance that contextual characteristics, such as NPSC, can have in explaining the relationship neighbourhood disadvantage and physical function. Such findings are also promising in terms of public health interventions. Interventions aimed at improving safety within the neighbourhood, integrated with supportive environments for physical activity, may have beneficial impacts on the population’s physical function. The National Heart Foundation of Australia [336] for example has disseminated a blueprint for community and neighbourhood designs that support active living. These include the enhancement of natural surveillance of street and open spaces, removing graffiti and repairing vandalism damage to enhance perceptions of safety that supports physical activity; the implementation of such measures may reduce neighbourhood inequalities in physical function.

5.6 Conclusion

This study found a graded relationship between neighbourhood-level socioeconomic disadvantage and physical function, and this was partly explained by differences in NPSC and WfR between disadvantaged and advantaged neighbourhoods. This study adds to the limited understanding of neighbourhood disadvantage and physical function, which could in turn, inform more effective interventions for maintenance of physical function. These findings call for further investigations of the complex interplay between environmental- and individual-level mechanisms in relation to health. Policies and interventions that act on the mechanisms identified in this study may help to mitigate neighbourhood inequalities in physical function.

CHAPTER 6: CAN WALKABILITY AND WALKING FOR TRANSPORT REDUCE NEIGHBOURHOOD INEQUALITIES IN PHYSICAL FUNCTION? A CASE STUDY AMONG MIDDLE-AGED TO OLDER ADULTS IN BRISBANE

This chapter presents Study Three of the thesis. This study examined whether neighbourhood walkability and walking for transport explain differences in physical function between advantaged and disadvantaged neighbourhoods.

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6.1 Abstract

Residents of socioeconomically disadvantaged neighbourhoods present with poorer physical function than their advantaged counterparts, although the reasons for this discrepancy remain unknown. This study examined the role of walkability (and its components) and walking for transport to this relationship using data from the 2013 HABITAT study among 4,723 men and women aged 46–72 living in 200 neighbourhoods in Brisbane, Australia. The findings indicated clear inverse associations between neighbourhood disadvantage and physical function in men and women. The findings also revealed a complex web of relationships between neighbourhood disadvantage, walkability, walking for transport and physical function, with clear gender differences. Overall, the relationship between neighbourhood disadvantage and physical function was not explained by walkability and walking for transport. Further research is required to better understand the underlying mechanisms.

6.2 Introduction

Epidemiological studies show that residents of disadvantaged neighbourhoods have poorer physical function than their counterparts from advantaged neighbourhoods [80, 116, 119, 122, 308]. The underlying mechanisms contributing to this relationship however, have not been rigorously investigated. Previous studies in Brisbane found that socioeconomically disadvantaged neighbourhoods have built environments that are conducive to walking for transport (WfT), and as a consequence, residents within these neighbourhoods engage in more transport walking than their counterparts from socioeconomically advantaged neighbourhoods [161, 337]. Arguably, more WfT is likely to be protective against poorer physical function; hence higher levels of WfT in disadvantaged neighbourhoods potentially dampen what would otherwise be larger neighbourhood-based inequalities in physical function. The aim of this paper is to test this proposition. If confirmed, the result will provide important information about how the built environment of disadvantaged neighbourhoods might mitigate health inequalities in physical function, as well as chronic diseases related to poorer physical function, by increasing opportunities for instrumental physical activity.

The built environment and walking for transport

In the physical activity literature, one of the key built environment characteristics that support activity and WfT in particular, is neighbourhood walkability [202, 338]. Walkability is typically characterised by street connectivity, density and land use mix [48, 73], or a composite measure that combines each of these built environment features. Street connectivity is the directness and availability of alternative routes from one point to another within a neighbourhood [339]. Dwelling density is the total number of dwellings per hectare of residential land within a neighbourhood, and land use mix is the mix of different classification of land uses (commercial, industrial, leisure/recreation, residential and other) within a neighbourhood [339]. A systematic review of the association between the built environment and active transport in older adults found that more walkable neighbourhoods (higher street connectivity, dwelling density, land use mix and/or walkability index) are consistent correlates and predictors of WfT [202]. However, findings from the systematic review should be interpreted with caution due to limitations associated with using a single composite measure of walkability (i.e., a walkability index) that combines multiple built environment characteristics. Grafova et al. [238] argue that focusing on a single built environment measure may incorrectly attribute health effects to the wrong neighbourhood characteristics; however, indexes are also potentially problematic as they combine multiple environmental attributes that may mask attributes that matter most to health. Therefore, using both single built environment components as well as a combined measure is likely to overcome possible limitations each measure may have pose to examine what is most important for health.

Walkability and physical function

A number of cross-sectional studies and one longitudinal study have examined the relationship between neighbourhood walkability (and its components) and physical function. Clarke and George [110] found that some components of walkability were related to the disablement process: neighbourhoods with limited land use mix were associated with poorer physical functioning among older adults. In a large sample of adults aged 50 and over, Freedman et al. [113] found that street connectivity was associated with a reduced risk of limitations in instrumental activities of daily living among men. King et al. [198] found that those with the lowest levels of physical function living in walkable neighbourhoods walked more than those with the highest levels of physical function living in less walkable neighbourhoods: these findings indicated that residing in a walkable neighbourhood supports people's ability to undertake everyday activities within neighbourhoods, even among those with lower levels of physical function.

In light of existing evidence, walkability is likely to play an important role in the relationship between neighbourhood disadvantage and physical function through its influence on transport walking. It is therefore, plausible that 'walkable' disadvantaged neighbourhoods that are conducive to more WfT are likely to have a protective effect on physical function; whereas 'low walkable' disadvantaged neighbourhoods that discourage transport walking are likely to exacerbate neighbourhood inequalities in physical function.

Based on the limited evidence to date, a conceptual framework that postulates the complex relationships between neighbourhood disadvantage, walkability, WfT and physical function is shown in Figure 6.1. The aim of this paper is to investigate whether neighbourhood walkability and WfT explained differences in physical function between advantaged and disadvantaged neighbourhoods.

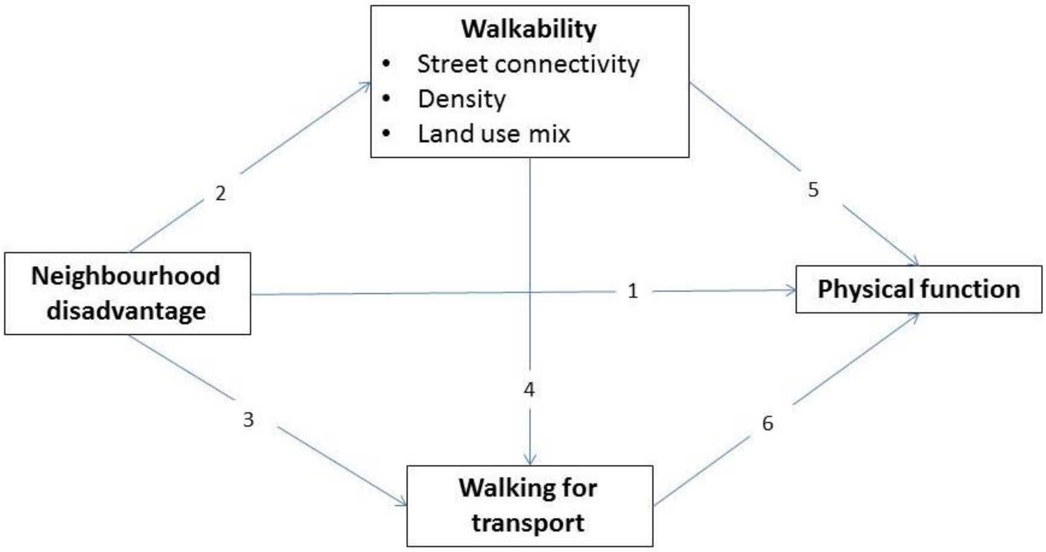

Figure 6.1: Conceptual framework of the association between neighbourhood disadvantage, walkability, walking for transport and physical function. Each number depicts an analytic pathway that is explored in this study.

To test the relationships depicted in the framework, the following hypotheses were examined:

1. Residents of disadvantaged neighbourhoods will have lower levels of physical function (pathway 1);
2. Disadvantaged neighbourhoods will have more connected street network, greater dwelling density, more diverse mix of land uses and higher walkability scores (pathway 2);
3. Those living in disadvantaged neighbourhoods will walk more for transport (pathway 3);
4. Residents of neighbourhoods with higher walkability scores (more connected streets, greater dwelling density and more diverse mix of land uses) will walk more for transport (pathway 4);
5. Residents of neighbourhoods with higher walkability scores will have better physical function (pathway 5);

6. Residents who walk more for transport will have better physical function (pathway 6); and
7. Differences in physical function between advantaged and disadvantaged neighbourhoods will widen after adjustment for street connectivity, dwelling density and land use mix because disadvantaged neighbourhoods in Brisbane have built environments that are more conducive to WfT.

6.3 Methods

6.3.1 Study population

This investigation uses data from the HABITAT (How Areas in Brisbane Influence HealTh and AcTivity) study. HABITAT is a multilevel longitudinal study of mid-aged adults living in the Brisbane Local Government Area, Australia [321]. Brisbane has a medium density urban environment, with a population of approximately 2.3 million [280] and a median age of 35 in 2014 [213].The primary aim of HABITAT is to examine patterns of change in health and well-being over the period 2007 – 2016, and to assess the relative contributions of environmental, social, psychological and socio-demographic factors to these changes. The HABITAT study received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3967H & 1300000161).

6.3.2 Sample

Details about HABITAT's baseline sampling have been published elsewhere [217]. Briefly, a multi-stage probability sampling design was used to select a stratified random sample (n = 200) of CCD, and from within each CCD, a random sample of people aged 40-65 years (on average 85 per CCD). CCDs are embedded within a larger suburb, hence the area corresponding to, and immediately surrounding, a CCD is likely to have meaning and significance for their residents: for this reason, we hereafter use the term ‘neighbourhood’ to refer to each CCD. The baseline HABITAT sample (2007) was broadly representative of the wider Brisbane population [321].

6.3.3 Data collection and response rates

A structured self-administered questionnaire was developed, and copies were sent to 17,000 potentially eligible participants in May 2007 using a mail survey method developed by Dillman [220]. After excluding out-of-scope respondents (i.e., deceased, no longer at the last known address, unable to participate for health-related reasons), 11,035 usable surveys were returned, yielding a baseline response rate of 68.3%.The corresponding response rates from in-scope and contactable participants in 2009, 2011, 2013 and 2016 were 72.6% (n = 7,866), 67.3% (n = 6,900), 67.1% (n = 6,520), and 57.2% (n = 5,188) respectively. For this study, data collected within the 2013 survey was used, as physical function was first measured at this wave.

6.3.4 Neighbourhood-level measures

Neighbourhood socioeconomic disadvantage

Each neighbourhood was assigned a socioeconomic score using the ABS’ IRSD [228]. A neighbourhood’s IRSD score reflects each area’s overall level of disadvantage measured on the basis of 17 variables that capture a wide range of socioeconomic attributes, including: education, occupation, income, unemployment, household structure, and household tenure (plus others). The derived socioeconomic scores from each of the HABITAT neighbourhoods were then grouped into quintiles based on their IRSD scores, with Q1 denoting the twenty-percent most advantaged areas relative to the whole of Brisbane, and Q5 the most disadvantaged twenty-percent.

Built environment measures

The neighbourhood-level data used to derive the objectively measured street connectivity, dwelling density and land use mix were provided by the Brisbane City Council (the local government authority responsible for the jurisdiction covered by the HABITAT study) and Pitney Bowes StreetPro [340]. In this sample, the HABITAT neighbourhoods consist of 55 individuals on average (standard deviation of 28), ranging from 12-161 individuals. The size of the 200 HABITAT neighbourhoods ranged from 19,969 to 70,673,184 square meters. As recommended by Lamb and White [239], the built environment measures were entered into the analytic models as continuous variables. Although it is common for researchers to categorise built environment measures (binary, tertiles, quartiles, quintiles or other levels of arbitrary categorisation), categorising built environment measure leads to a loss of information, lack of replicability between studies, and potential bias due to choice of cut-point [239].

Street connectivity

Street connectivity was calculated as a count of the number of four-way or more intersections within each neighbourhood. Greater connectivity indicates more choices en route and often a more direct travel route between origin and destination. The mean street connectivity was 2.94 (Standard Deviation [SD] 2.37) and the median was 2 four-way or more intersections per neighbourhood respectively, ranging from 0 to 12.

Dwelling density

Dwelling density was calculated as the number of dwellings per hectare of residential land within each neighbourhood. Larger values represent greater density. For this analysis, dwelling density was divided by 100 so that the coefficient is interpreted as a 100 dwelling increase in density. The mean dwelling density was 17.78 (SD 7.54) per neighbourhood with a range from 0.2 to 49.

Land use mix

Land use mix was calculated using five classifications of land use: commercial, industrial, leisure/recreation, residential and other using the equation from Leslie et al (2007) [240], which results in a score ranging between 0 and 1. A score of 0 indicates that all land uses are of a single type and a score of 1 indicates that the area has an even distribution of land-use mix. Larger number represents a more heterogeneous distribution of land use. For this analysis, the land use variable was multiplied by 10 so that the coefficient is interpreted as a 0.1 (or 10%) increase in land use mix. The mean and median land use mix was 3.3 and 3.1 (SD 1.48), respectively per neighbourhood, ranging from 0 to 7.5.

Walkability

Walkability is a composite measure of (i) street connectivity, (ii) dwelling density and (iii) land use mix. Each of these variables were standardized and summed to generate a walkability index: these types of indices have been extensively validated [193, 241, 242]. The mean walkability index was 0.003 (SD 1.81) per neighbourhood, ranging from -5.56 to 4.18.

Neighbourhood self-selection

To assess residential attitudes, participants were asked to respond on a five-item Likert scale, ranging from ‘not at all important’ to ‘very important’ to 14 statements regarding ‘How important were the following reasons for choosing your current address?’ Examples of items included: ‘Ease of walking to places’, ‘Closeness to schools’, ‘Closeness to open spaces (e.g., parks)' and 'Closeness to public transport'. PCA with varimax rotation showed that 12 of the items loaded onto one factor, subsequently described as 'neighbourhood self-selection' (α = .84).

6.3.5 Individual-level measure, covariates and confounding

Walking for transport

This was measured using a single question that asked respondents to report how much time (minutes) they had spent WfT in the previous week (i.e., travel to and from work, to do errands, or to go from place to place). The distribution of the transport walking variable was zero-inflated (60% of the sample were 'non-transport walkers'), and only 6% of the sample reported walking at least 150 minutes or more per week. Due to the small proportion of the sample being in the moderate to high category for transport walking, the transport walking variable was recoded as none (0 minutes) and any (at least 1 minute or more).

Self-reported physical function

This was measured using the Physical Function Scale (PF-10), a component of the Short Form 36 (SF-36) Health Survey [283]. The stem question of the PF-10 asked 'Does your health now limit you in these activities? If so, how much?'. Respondents were given the following choices as response for each activity: 'Yes, limited a lot' or 'Yes, limited a little' or 'No, not limited at all'. The PF-10 measures a hierarchical range of difficulties, from vigorous activities, such as lifting heavy objects to bathing and dressing[327]. This measure has been extensively validated among community-dwelling adults using convergent validity calculated by Pearson Correlations using 3-performance based measures: single limb stance as an indicator of balance ($r = 0.42$), Time Up and Go test as a measure of mobility ($r = -0.70$) and gait speed as an indicator of overall functional capacity ($r = 0.75$) [25]. The method of data cleaning for the physical function score was adapted from Ware et al. [283]. The raw physical function scores were calculated as the sum of (re-coded) scale items and transformed to a 0 to 100 scale. A standard scoring system was used such that 0 represents minimal functioning, and 100 represents maximal functioning.

Education

Respondents were asked to provide information about the highest education qualification completed. Respondents were coded as (i) Bachelor degree or higher (the latter included postgraduate diploma, master's degree, or doctorate), (ii) Diploma (associate or undergraduate), (iii) Vocational (trade or business certificate or apprenticeship), and (iv) No post-secondary school qualification.

Occupation

Respondents who were employed at the time of completing the survey were asked to indicate their job title and then to describe the main tasks or duties they performed. This information was coded to the ASCO. For the purpose of this study, the original ASCO classification was recoded into three categories: (i) Managers/professionals, (ii) White-collar employees, and (iii) Blue-collar employees. Respondents who were not employed were categorised as follows: (iv) Home duties, (v) Retired, (vi) Permanently unable to work.

Household income

Respondents were asked to indicate their total annual household income (including pensions, allowances and investments) using a 14-category measure that was subsequently recoded into six groups for analysis: (i) AU$130,000 or more, (ii) AU$72,800-129,999, (iii) AU$41,600-72,799, (iv) AU$26,000-41,599, (v), Less than AU$25,999, and (vi) Not classified (i.e., ticked 'Don't know' or 'Don't want to answer this', or left the income question blank).

Distance from Central District Business (CBD)

A previous study [161] found that distance from the CBD confounded the relationship between neighbourhood disadvantage, built environment and walking for transport. To account for this confounding, some models were adjusted for distance from the CBD where deemed appropriate (see Statistical analysis). Distance from the CBD was obtained from the GIS data by measuring the straight line distance (km) between the CBD and each respondent's dwelling.

6.3.6 Statistical analysis

These cross-sectional analyses used data from the 2013 HABITAT survey. We excluded respondents who had moved since 2007 (n = 1,342), as relocating to a different neighbourhood may have been be influenced by unmeasured preferences related to both residential choice and physical function [328]. Hence, 200 neighbourhoods were included in the analyses. Participants with missing data for physical function (n = 80), education (n = 14) and WfT (n = 137), neighbourhood self-selection (n = 224) were also excluded. This reduced the analytic sample to n = 4,723. Sensitivity analyses (not presented here) revealed that those excluded due to missing data did not significantly differ from included participants on neighbourhood disadvantage, education, WfT and physical function. As previous studies have found gender differences in response to questions about neighbourhood contexts, as well as physical function profile, analyses were stratified by gender [113, 261, 308, 320].

Multilevel modelling is the appropriate statistical technique for these analyses as it offers a robust and efficient approach to the examination of hierarchical data where individuals are nested (clustered) within neighbourhoods [285]. The analyses were conducted in seven stages. First, the relationship between neighbourhood disadvantage and physical function was examined using multilevel linear regression (MLLR), and the data were graphically presented as mean differences in function between the neighbourhood quintiles, adjusted for age, individual-level socioeconomic position (SEP) and neighbourhood self-selection. Second, the association between neighbourhood disadvantage and mean walkability score (and its components) was examined using One Way Analysis of Variance, with correction for multiple comparisons using the Bonferroni test. Third, the association between neighbourhood disadvantage and WfT was examined using multilevel multinomial logistic regression: Model 1 adjusted for age, individual-level SEP, neighbourhood self-selection and distance from the CBD; Models 2 to 5 included Model 1, as well as street connectivity, dwelling density, land use mix and walkability, respectively. As recommended [265], the parameters for these models –odds ratios and 95% credible intervals– were estimated using Markov Chain Monte Carlo simulation. This procedure was implemented using the Metropolis-Hasting algorithm with standard non-informative prior distributions on all parameters. Fourth, the association between built environment features and WfT was examined using the procedure outlined in step three. Fifth, the association between walkability (and its components) and physical function was examined using MLLR: the model was adjusted for age, individual-level SEP, neighbourhood disadvantage and neighbourhood self-selection. Sixth, the association between WfT and physical function was examined using the procedure outlined in step five. Seventh, the contribution of neighbourhood walkability and WfT to the association between neighbourhood disadvantage and physical function was examined using MLLR: In Model 1, mean differences in physical function across quintiles of neighbourhood disadvantage were adjusted for age, individual SEP, neighbourhood disadvantage and neighbourhood self-selection. In Models 2-6, each of street connectivity, dwelling density, land use mix, walkability and WfT were analysed in separate models. Model 7 included street connectivity, dwelling density, land use mix and WfT. All data were prepared in STATA SE 13 [267] and the analyses were conducted using MLwiN version 2.35 [288].

6.4 Results

Sociodemographic characteristics and mean physical function score of the study sample are shown in Table 6.1. Mean physical function scores were lowest among residents of the most disadvantaged neighbourhoods, the least educated, those who were permanently unable to work, members of low income households, and those in the oldest age group. Physical function scores were also lowest for those reporting 0 minutes of WfT in the previous week.

Table 6.1: Socio-demographic characteristics and mean (95% confidence interval) physical function scores for the HABITAT analytic sample in 2013[a]

	Men (n = 2013)		Women (n = 2710)	
	(%)	**Mean (95% CI)**	**(%)**	**Mean (95% CI)**
Neighbourhood disadvantage				
Q1 (least disadvantaged)	20.9	91.7 (90.5, 92.9)	20.5	87.8 (86.5, 89.2)
Q2	27.3	90.1 (88.9, 91.3)	27.2	85.6 (84.3, 86.9)
Q3	20.7	87.1 (85.5, 88.7)	19.2	83.2 (81.6, 84.9)
Q4	18.0	84.9 (82.9, 86.9)	18.9	80.4 (78.6, 82.2)
Q5 (most disadvantaged)	12.9	79.7 (76.7, 82.6)	14.1	74.9 (72.3, 77.6)
Age				
45-49 years	20.2	91.8 (90.5, 93.1)	18.8	89.4 (87.8, 90.8)
50-54 years	21.8	89.4 (87.8, 90.9)	21.2	86.0 (84.5, 87.6)
55-59 years	20.7	87.0 (85.3, 88.7)	20.6	84.2 (82.8, 85.7)
60-65 years	19.7	85.7 (84.0, 87.6)	20.5	80.3 (78.5, 82.0)
66+ years	17.4	82.9 (80.8, 85.0)	18.7	75.4 (73.4, 77.4)
Education				
Bachelor degree or higher	36.3	90.9 (90.0, 91.8)	33.7	86.5 (85.3, 87.6)
Diploma/associate degree	12.4	89.3 (87.6, 91.1)	11.3	84.1 (82.0, 86.3)
Certificate	21.2	86.0 (84.0, 87.9)	13.9	83.9 (82.1, 85.9)
No post-school qualification	30.1	83.8 (82.2, 85.4)	41.0	79.8 (78.5, 81.2)
Occupation				
Professional	35.7	91.5 (90.6, 92.4)	29.1	89.3 (88.3, 90.3)
White collar	12.8	90.8 (89.3, 92.2)	25.1	86.1 (85.0, 87.3)
Blue collar	18.8	88.3 (86.6, 90.0)	4.7	86.2 (83.2, 89.3)
Home duties	0.7	80.0 (66.8, 93.1)	8.3	83.7 (81.1, 86.2)
Retired	20.9	82.6 (80.7, 84.6)	23.9	76.3 (74.6, 78.0)
Permanently unable to work	2.4	58.1 (50.0, 66.1)	1.8	33.7 (26.4, 41.1)
Not easily classifiable[b]	8.7	85.0 (81.7, 88.1)	7.1	80.1 (77.1, 83.4)
Income				
$130,000+	25.3	92.6 (91.7, 93.6)	16.3	90.5 (89.2, 91.8)
$72,800-129,999	24.4	89.4 (88.0, 90.7)	22.5	86.2 (85.0, 87.6)
$52,000-72,799	13.1	87.6 (85.6, 89.6)	11.6	84.2 (82.1, 86.3)
$26,000-51,999	18.5	83.7 (81.7, 85.8)	19.5	78.2 (76.4, 80.0)
Less than $25999	8.6	74.6 (70.8, 78.4)	11.7	72.9 (70.2, 75.6)
Not classified[c]	9.9	87.9 (85.4, 90.3)	18.3	83.7 (81.8, 85.5)
Walking for transport				
No	59.2	86.7 (85.7, 87.7)	64.0	81.9 (80.9, 82.9)
Yes	40.8	88.8 (87.7, 89.8)	36.0	85.4 (84.3, 84.5)

[a]Physical function score ranged from 0-100, where 0 represents minimal functioning and 100 represents maximal functioning. [b]Not easily classifiable: students, unemployed or other classifiable. [c]Not classified: those who reported ‘Don’t know’ or ‘Don’t want to answer this’, or left the income question blank.

Neighbourhood disadvantage and physical function

There was a strong, graded association between neighbourhood disadvantage and physical function for both men and women (Figure 6.2). After adjustment for age and potential confounders, residents living in the most disadvantaged neighbourhoods reported significantly poorer physical function than their counterparts living in the most advantaged neighbourhoods.

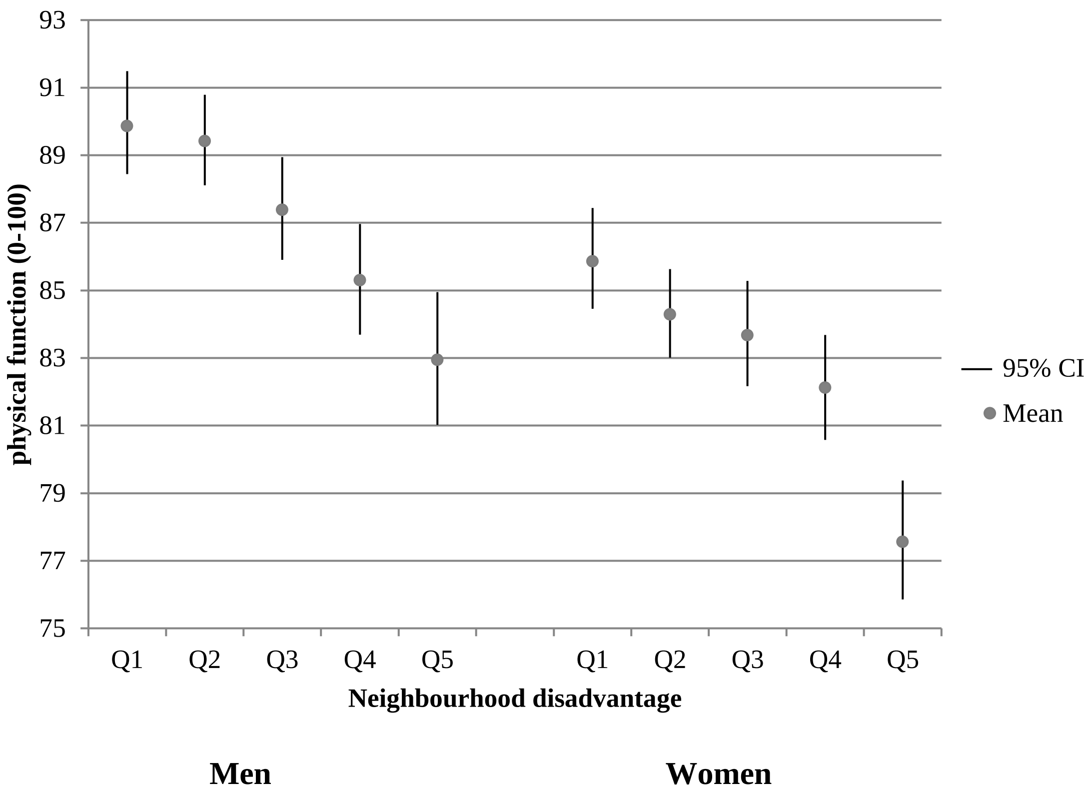

Figure 6.2: Relationship between neighbourhood disadvantage and physical function (0-100) for men and women. Model adjusted for within neighbourhood variation in age, education, occupation and household income. Q1 represents the least disadvantaged neighbourhood and also the reference group.

Neighbourhood disadvantage and built environment

Associations between neighbourhood disadvantage and built environment are shown in Table 6.2. Disadvantaged neighbourhoods were more residentially dense as well as more walkable than advantaged neighbourhoods. Neighbourhood disadvantage was not associated with street connectivity and land use mix.

Table 6.2: Association between neighbourhood disadvantage and components of walkability for men and women (mean and 95% confidence intervals)

Built environment (n=200 neighbourhoods)	**Street connectivity[b]**	**Density[c]**	**Land use mix[d]**	**Walkability**
Neighbourhood disadvantage[a]	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**
Q1 (least disadvantaged)	2.67 (2.10, 3.23)	14.56 (12.31, 16.81)	2.93 (2.49, 3.37)	-1.09 (-1.20, -0.98)
Q2	2.28 (1.64, 2.92)	16.39 (13.94, 18.83)	3.25 (2.78, 3.73)	-0.18 (-0.32, -0.05)*
Q3	3.50 (2.66, 4.33)	19.75 (17.41, 22.10)*	3.22 (2.79, 3.66)	0.59 (0.46, 0.73)*
Q4	3.00 (2.36, 3.63)	18.32 (16.63, 20.00)	3.76 (3.28, 4.23)	0.69 (0.54, 0.84)*
Q5 (most disadvantage)	3.32 (2.39, 4.25)	19.83 (17.25, 22.41)*	3.43 (2.98, 3.88)	0.51 (0.34, 0.66)**
Overall p value	0.13	< 0.01	0.06	< 0.01

[a]Neighbourhood disadvantage information was obtained from the census that summarises the socioeconomic conditions of geographic areas; [b]street connectivity ranged from 0 to 12; [c]density ranged from 0.2 to 49; [d]land use mix ranged from 0 to 9.11. Abbreviations: OR, odds ratio, CI, confidence intervals. Statistical significance indicated by *p<0.05, **p<0.01 using Bonferroni test that provided pairwise comparison of the means across neighbourhood disadvantage (Q1 as reference group).

Neighbourhood disadvantage and walking for transport

Associations between neighbourhood disadvantage and WfT are shown in Table 6.3. Among men, no significant associations were found between neighbourhood disadvantage and WfT.

Among women, the odds of WfT were approximately a third higher in the disadvantaged neighbourhoods for all models, although neighbourhood differences did not reach statistical significance. Those living in the more disadvantaged neighbourhoods were significantly more likely to WfT after adjusting for age, individual-level SEP, distance from the CBD and neighbourhood self-selection (Model 1). After adjusting for street connectivity (Model 2), dwelling density (Model 3), land use mix (Model 4) and walkability index (Model 5), the associations attenuated to the null.

Table 6.3: Associations between neighbourhood disadvantage and walking for transport for men and women (odds ratio and 95% credible intervals)

Neighbourhood disadvantage[a]	Walking for transport									
	Model 1[b] OR (95% CrI)		Model 2[c] OR (95% CrI)		Model 3[d] OR (95% CrI)		Model 4[e] OR (95% CrI)		Model 5[f] OR (95% CrI)	
	Baseline model		Street connectivity		Dwelling density		Land use mix		Walkability	
	None	Yes	None	Yes	None	Yes	None	Yes	None	Yes
Men (n = 2013)										
Q1 (least disadvantage)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Q2	1.00	0.92 (0.72, 1.16)	1.00	0.92 (0.72, 1.16)	1.00	0.84 (0.66, 1.06)	1.00	0.92 (0.73, 1.17)	1.00	0.89 (0.66, 1.20)
Q3	1.00	1.03 (0.75, 1.41)	1.00	1.00 (0.74, 1.36)	1.00	0.83 (0.60, 1.13)	1.00	1.03 (0.69, 1.24)	1.00	0.96 (0.69, 1.35)
Q4	1.00	1.11 (0.79, 1.56)	1.00	1.09 (0.78, 1.54)	1.00	0.86 (0.59, 1.26)	1.00	1.14 (0.80, 1.63)	1.00	1.03 (0.72, 1.49)
Q5 (most disadvantage)	1.00	1.16 (0.79, 1.71)	1.00	1.12 (0.77, 1.63)	1.00	0.88 (0.61, 1.26)	1.00	1.18 (0.80, 1.74)	1.00	1.09 (0.73, 1.62)
Women (n = 2710)										
Q1 (least disadvantage)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Q2	1.00	1.13 (0.86, 1.52)	1.00	1.10 (0.83, 1.47)	1.00	1.08 (0.82, 1.43)	1.00	1.08 (0.81, 1.45)	1.00	1.07 (0.81, 1.41)
Q3	1.00	1.39 (1.01, 1.88)*	1.00	1.29 (0.94, 1.76)	1.00	1.26 (0.92, 1.74)	1.00	1.32 (0.97, 1.45)	1.00	1.27 (0.92, 1.75)
Q4	1.00	1.47 (1.03, 2.07)*	1.00	1.36 (0.97, 1.89)	1.00	1.30 (0.92, 1.85)	1.00	1.36 (0.97, 1.88)	1.00	1.33 (0.95, 1.87)
Q5 (most disadvantage)	1.00	1.46 (1.03, 2.08)**	1.00	1.37 (0.96, 1.94)	1.00	1.28 (0.88, 1.87)	1.00	1.36 (0.96, 1.94)	1.00	1.34 (0.93, 1.90)

Notes: Statistical significance indicated by *p<0.05, **p<0.01. Abbreviations: OR, odds ratio, CrI, credible intervals.
[a]Neighbourhood disadvantage information was obtained from the census that summarises the socioeconomic conditions of geographic areas; [b]Model 1: adjusted for age education, occupation, household income, distance from CBD and self-selection; [c]Model 2: Model 1 plus street connectivity; [d]Model 3: Model 1 plus dwelling density; [e]Model 4: Model 1 plus land use mix; [f]Model 5: Model 1 plus walkability.

Walkability and walking for transport

Table 6.4 shows relationships between walkability and WfT for men and women, after adjustment for individual-level SEP, neighbourhood disadvantage and neighbourhood self-selection. Among men, an increase in street connectivity, dwelling density (100 dwellings) and walkability was associated with a higher odds of WfT. However, there was no association between land use mix and the odds of WfT.

Among women, a one unit increase in street connectivity, dwelling density, land use mix and walkability was associated with higher odds of WfT.

Table 6.4: Associations between street connectivity, dwelling density, land use mix, walkability and walking for transport for men and women (odds ratio and 95% credible intervals)

Built environment	**Walking for transport**	
	None	**Yes OR (95% CrI)**
Street connectivity[a]		
Men (n = 2013)	1.00	1.04 (1.01, 1.09)*
Women (n = 2710)	1.00	1.06 (1.02, 1.11)*
Dwelling density[b]		
Men	1.00	1.05 (1.03, 1.07)*
Women	1.00	1.03 (1.02, 1.05)*
Land use mix[c]		
Men	1.00	0.98 (0.91, 1.06)
Women	1.00	1.06 (1.01, 1.15)*
Walkability index		
Men	1.00	1.06 (1.01, 1.14)*
Women	1.00	1.06 (1.01, 1.14)*

Notes: Statistical significance indicated by *p<0.05. Abbreviations: OR, odds ratio, CrI, credible intervals. Model adjusted for age, education, occupation, household income, neighbourhood disadvantage, distance from CBD and self-selection.
[a]A unit increase in street connectivity is equivalent to one four-way or more intersections. [b]A unit increase in dwelling density is equivalent to an increase of 100 dwellings. [c]A unit increase in land use mix is equivalent to a 10% increase in land use mix.

Associations between neighbourhood built environment and physical function are shown in Table 6.5. Among men, components of walkability were not associated with physical function after adjusting for age, individual-level SEP, neighbourhood disadvantage and neighbourhood self-selection. However, walkability index was positively associated with physical function.

Among women, no association was found between street connectivity, walkability and physical function after adjusting for age, individual-level SEP, neighbourhood disadvantage and self-selection. After adjustment for confounders, a one unit increase in dwelling density was significantly associated with poorer physical function, while a one unit increase in land use mix was positively associated with physical function, although at borderline significance (p=0.051).

Table 6.5: Associations between the built environment and physical function in men and women (β coefficient and 95% confidence intervals)

Built environment	**Physical function[a]** β **(95% CI)**	
	Men (n = 2013)	**Women (n = 2710)**
Street connectivity[b]	-0.21 (-0.51, 0.08)	-0.12 (-0.50, 0.09)
Dwelling density[c]	0.01 (-0.12, 0.15)	-0.16 (-0.29, -0.03)*
Land use mix[d]	0.46 (-0.03, 0.97)	0.46 (-0.01, 0.93)
Walkability index	0.45 (0.01, 0.89)*	-0.13 (-0.01, 0.01)

Notes: Statistical significance indicated by *p<0.05. Abbreviations: β, beta coefficient; CI, confidence intervals. Model adjusted for age, education, occupation and household income, neighbourhood disadvantage and self-selection. [a]Physical function score ranged from 0-100, where 0 represents minimal functioning and 100 represents maximal functioning. [b]A unit increase in street connectivity is equivalent to one four-way or more intersections. [c]A unit increase in dwelling density is equivalent to an increase of 100 dwellings. [d]A unit increase in land use mix is equivalent to a 10% increase in land use mix.

Walking for transport and physical function

After adjustment for confounders, no significant association was found between WfT and physical function among men (β: 0.62, 95% CI: -0.80, 2.04). Among women, those who walked for transport had significantly better physical function than those who did not (β: 2.72, 95% CI: 1.30, 4.15).

Associations between neighbourhood disadvantage and physical function before (Model 1) and after adjusting for street connectivity (Model 2), dwelling density (Model 3), land use mix (Model 4), walkability (Model 5), WfT (Model 6) and the fully adjusted model (street connectivity, dwelling density, land use mix and WfT; Model 7), are shown in

Table 6.6. After adjustment for components of walkability, the walkability index, and WfT (Models 2-7), the association between neighbourhood disadvantage and physical function remained statistically significant and largely unchanged from the baseline model.

Table 6.6: Relationship between neighbourhood disadvantage and physical function[a] adjusting for individual-level socioeconomic position (Model 1), street connectivity (Model 2), dwelling density (Model 3), land use mix (Model 4), walkability (Model 5) and walking for transport (Model 6) in men and women (β coefficient and 95% confidence intervals)

Neighbourhood disadvantage[b]	**Model 1[c] β (95% CI)**	**Model 2[d] β (95% CI)**	**Model 3[e] β (95% CI)**	**Model 4[f] β (95% CI)**	**Model 5[g] β (95% CI)**	**Model 6[h] β (95% CI)**	**Model 7[i] β (95% CI)**
Men (n = 2013)							
Q1 (least disadvantage)	-	-	-	-	-	-	-
Q2	-0.42 (-2.46, 1.61)	-0.43 (-2.47, 1.60)	-0.47 (-2.52, 1.57)	-0.47 (-2.51, 1.55)	-0.77 (-2.83, 1.29)	-0.41 (-2.38, 2.30)	-0.49 (-2.54, 1.55)
Q3	-2.45 (-4.67, -0.23)*	-2.28 (-4.52, -0.04)*	-2.57 (-4.85, -0.29)*	-2.57 (-4.80, -0.35)*	-3.10 (-5.41, -0.80)**	-2.43 (-4.66, -0.21)*	-2.45 (-4.74, -0.15)**
Q4	-4.56 (-6.89, -2.23)***	-4.47 (-6.80, -2.13)***	-4.69 (-7.08, -2.30)***	-4.93 (-7.29, -2.57)***	-5.29 (-7.72, -2.86)***	-4.54 (-6.87, -2.21)***	-4.89 (-7.31, -2.47)***
Q5 (most disadvantage)	-6.89 (-9.52, -4.26)***	-6.71 (-9.35, -4.07)***	-7.03 (-9.72, -4.33)***	-7.15 (-9.79, -4.51)***	-7.51 (-10.20, -4.82)***	-6.87 (-9.50, -4.24)***	-7.02 (-9.73, -4.31)***
Women (n = 2710)							
Q1 (least disadvantage)	-	-	-	-	-	-	-
Q2	-1.55 (-3.53, 0.42)	-1.52 (-3.50, 0.45)	-1.41 (-3.40, 0.57)	-1.69 (-3.68, -0.28)	-1.46 (-3.48, 0.54)	-1.57 (-3.54, 0.40)	-1.45 (-3.46, 0.55)
Q3	-2.16 (-4.34, 0.01)	-1.98 (-4.19, 0.22)	-1.79 (-4.03, 0.44)	-2.35 (-4.53, -0.16)*	-1.99 (-4.28, 0.28)	-2.27 (-4.45, -0.10)*	-2.06 (-4.34, 0.21)
Q4	-3.74 (-5.97, -1.51)**	-3.59 (-5.84, -1.35)**	-3.33 (-5.63, -1.03)**	-4.14 (-6.40, -1.87)***	-3.56 (-5.91, -1.21)**	-3.79 (-6.01, -1.56)**	-3.56 (-5.90, -1.22)**
Q5 (most disadvantage)	-8.28 (-10.70, -5.85)***	-8.17 (-10.60, -5.74)***	-7.76 (-10.29, -5.24)***	-8.65 (-11.10, -6.20)***	-8.12 (-10.63, -5.61)***	-8.33 (-10.75, -5.91)***	-8.12 (-10.63, -5.62)***

Notes: Statistical significance indicated by *p<0.05, **p<0.01, ***p<0.001. Abbreviations: β, beta coefficient; CI, confidence intervals
[a]Physical function score ranged from 0-100, where 0 represents minimal functioning and 100 represents maximal functioning. [b]Neighbourhood disadvantage information was obtained from the census that summarises the socioeconomic conditions of geographic areas. [c]Model 1: adjusted for age, education, occupation and household income and self-selection. [d]Model 2: Model 1 plus adjustment for street connectivity. [e]Model 3: Model 1 plus adjustment for dwelling density. [f]Model 4: Model 1 plus adjustment for land use mix. [g]Model 5: Model 1 plus adjustment for walkability. [h]Model 6: Model 1 plus adjustment for walking for transport; [i]Model 7: Model 1 plus street connectivity, dwelling density, land use mix and walking for transport.

6.5 Discussion

This study examined whether neighbourhood walkability and WfT explained differences in physical function between advantaged and disadvantaged neighbourhoods. Consistent with previous research [116, 119, 122], this study found that living in more disadvantaged neighbourhoods was associated with poorer physical function among men and women after adjusting for individual-level SEP. Further, disadvantaged neighbourhoods were more walkable and residentially dense, and women living in disadvantaged neighbourhoods were more likely to walk for transport. However, this study found no compelling evidence that neighbourhood walkability and WfT explained the relationship between neighbourhood disadvantage and physical function for men or women.

Previous research has often characterised disadvantaged neighbourhoods as lacking environmental features that are supportive of physical activity [193, 341]. However, consistent with previous HABITAT research [161] , this study found that individuals residing in more disadvantaged neighbourhoods were more likely to walk for transport [128], partly due to greater dwelling density and walkability.

Walking is a common and cost-effective physical activity intervention for disadvantaged and less physically active populations (women, older adults, those of low socioeconomic status, and those living in more disadvantaged areas) [64, 342, 343]. The findings of this study suggest that, in the presence of a walkable built environment, residents of disadvantaged neighbourhoods are indeed more likely to walk for transport. This finding from the City of Brisbane could empower policy makers from other jurisdictions to seek to reduce health inequities between advantaged and disadvantaged neighbourhoods by developing more supportive built environments.

This study found gender differences in the relationships between neighbourhood walkability, WfT and physical function. Among men, no relationship was found between these factors, therefore, the hypothesis that neighbourhood walkability and WfT contribute to the relationship between neighbourhood disadvantage and physical function among men was not supported. Among women, those living in more disadvantaged neighbourhoods walked more for transport and those who walked had significantly better physical function. While it is unclear why the gender difference exists, previous research suggests that, for WfT, women are more sensitive to the neighbourhood environment than men [344]. Mixed associations were found between each component of walkability and physical function: dwelling density was negatively associated with physical function, and land use mix was positively associated. Although the reasons for these findings are unclear, it is possible that the components of walkability do not associate with physical function in a linear way. A systematic review of the relationship between the built environment and active travel reported a curvilinear relationship between density and active travel [202]. Increasing density in an already dense area may result in a decrease in WfT, possibly due to higher levels of pollution (noise and air) and traffic hazards in dense areas [202], which have been associated with poorer physical function [80]. However, a post-hoc analysis in this study did not reveal a curvilinear relationship between dwelling density and WfT. A review paper by Andrews et al. [243] criticised the existing walkability and health research as a large number of studies often assumed a deterministic relationship between walkability and the tendency of people to walk which, in turn, determines their health. He argued that it is important to consider the multiple scales of causation across differing physical, social and cultural environments factors that may enhance or impede health.

An implication derived from this study's findings is that combining street connectivity, density and land use mix to form a walkability index may not be an appropriate approach in understanding physical function, even though walkability has been extensively validated and consistently associated with several health outcomes [244]. It is possible that the negative and positive associations between dwelling density, land use mix and physical function produced null findings when combined as a single 'walkability' measure, thus making it difficult to provide recommendations to policymakers about how to design neighbourhood built environments that are conducive to good physical function.

Limitations

A number of methodological and analytic issues need to be considered when interpreting this study's results. First, the cross-sectional nature of this analysis means that claims about causality are limited. However, this study adjusted for residential self-selection into neighbourhoods. A recent systematic review of the neighbourhood built environment and physical activity revealed that failing to include residential self-selection limits the inference that can be made from cross-sectional studies [345]. Second, the study data were obtained from the fourth wave (2013) of the HABITAT study. The non-response and sample attrition from baseline to the fourth wave may have implications for generalizability. An attrition analysis revealed that some demographic variables (education, occupation and household-income) were associated with drop-out between baseline and the fourth wave of HABITAT study, but not associated with WfT at baseline. When drop-out is associated to covariates only and not to prior values of outcome variables, the drop-out pattern is called (conditionally on the covariates) missing at random [346]. Third, the neighbourhood walkability measures used in this study were insufficient to capture the quality of neighbourhood built environment features. A US study suggested that the benefits of macroscale built environment features conducive to transport walking may not be realised in the presence of a poor quality pedestrian features (such as the uneven or cracked footpaths) [347]. Fifth, the generalisability of this study's findings will likely depend on a city's similarities to Brisbane, both in geographical area and population distribution, and specifically, the spatial patterning of socioeconomic disadvantage. Sixth, data on WfT and physical function were self-reported and therefore subject to recall and/or desirability bias [348]. Sixth, the geographic specificity where the walking activity was undertaken was not captured in the WfT survey item. Therefore, the possibility that participants reported walking outside of their neighbourhoods cannot be overlooked. In addition, the walking item in the survey was unable to capture the intensity of walking, which has shown to be more important to health than the total walking time [193]. Finally, the neighbourhood self-selection variable used in the study has not been previously validated. Therefore, findings from this study must be interpreted with caution.

To our knowledge, no prior published study has examined whether neighbourhood walkability and WfT explain differences in physical function between advantaged and disadvantaged neighbourhoods. Despite this study's finding that living in a walkable environment, and high levels of WfT did not explain the differences in physical function between advantaged and disadvantaged neighbourhoods, policy-makers should not be discouraged from improving neighbourhood walkability to reduce social health inequities. For instance, neighbourhood walkability has been positively associated with access to education, employment, health care services, shops and services: all of which are important to health [349].

There are a number of future research priorities. When studying physical function, it is recommended that associations are stratified by gender. This is illustrated by the marked gender differences in the relationships between neighbourhood walkability, WfT and physical function in this study's findings. Further, future studies investigating neighbourhood walkability and health should analyse the components of walkability separately rather than as a combined measure, as the nature of the association may operate differently, depending on the health or behavioural outcome.

6.6 Conclusion

The mechanisms linking neighbourhood disadvantage and physical function are complex. At least in Brisbane, this relationship did not appear to be explained by neighbourhood walkability or WfT. Clearly, neighbourhood socioeconomic inequalities in physical function appear to be influenced by factors not considered in this study. Further research is required to identify these factors.

CHAPTER 7: GENERAL DISCUSSION

7.1 Introduction

Each of the three studies in this thesis had its own discussion section that provided an interpretation of the study's findings in relation to the literature that discussed the strengths and limitations of each study, and the policy implications of each study for neighbourhood disadvantage and physical function. This chapter provides the 'big picture' perspective of how the findings of the three studies address the research questions and add to the current evidence base about how neighbourhood disadvantage influences physical function. The research limitations and recommendations for future research are also discussed.

7.2 Overall thesis aim

This thesis program broadly fits into the areas of social inequalities and health; neighbourhood and health; and physical function among an ageing population. The overarching aim of the thesis was to investigate the contributions of the neighbourhood environment in the relationship between neighbourhood disadvantage and physical function among middle-aged to older adults. Some of the pathways and mechanisms by which neighbourhood disadvantage and physical function are related were explored. Study One examined the relationship between neighbourhood disadvantage and physical function. Study Two explored the role of neighbourhood-level perceptions of safety from crime (NPSC) and walking for recreation (WfR) to the relationship between neighbourhood disadvantage and physical function. Study Three examined the role of the built environment (i.e., street connectivity, dwelling density, land use mix, and walkability) and walking for transport (WfT) in the relationship between neighbourhood disadvantage and physical function. The findings of this thesis contribute to the field of neighbourhood inequalities in health, and are both timely and relevant for public health challenge of finding ways to keep people physically active as they age so that they can maintain independence and age-in-place.

7.3 Overview of major findings

The analysis presented in Study One described a significant and graded association between neighbourhood disadvantage and physical function for both men and women, after adjusting for individual-level socioeconomic position (SEP). I found that residents living in the most disadvantaged neighbourhoods had, on average, poorer physical function. This has previously been reported in studies conducted in the US and UK, suggesting that the socioeconomic characteristics of the neighbourhood environment may have implications for physical function and that this phenomenon may be universal across developed countries [113, 116, 118, 119, 122]. In addition, Study One extended the analysis to test whether associations between education, occupation and household income differed across neighbourhoods that varied in their levels of socioeconomic disadvantage. The findings revealed that the association between education, occupation and household income and physical function differed across levels of neighbourhood disadvantage. Expressed another way, the relationship between neighbourhood disadvantage and physical function does not seem to affect all groups equally. The cross-level interaction analysis identified evidence of ‘double disadvantage’, whereby residents with the lowest education attainment living in the most disadvantaged neighbourhoods had the lowest physical function score. These findings showed that while individual- and neighbourhood-level factors may affect physical function independently, they also interact with one another to impact physical function synergistically. This is the first known study to examine the relationship between neighbourhood disadvantage and physical function in the Australian context and it has provided strong evidence in the field, reinforcing the need to unpack this association by researching the mechanism of this relationship.

Moving forward from the descriptive nature of the relationship addressed in Study One, Studies Two and Three explored the mechanistic pathways that may explain the relationship between neighbourhood disadvantage and physical function. Conceptually, we know that simply living in a disadvantage neighbourhood will not directly contribute to an individual's physical function; rather, it is what happens within the environments of disadvantaged neighbourhoods that are likely to contribute to poorer physical function. Acknowledging that there are many factors in a neighbourhood that may be associated with physical function (such as smoking behaviour, alcohol consumption and diet), physical activity was chosen as one of the possible explanatory factor [24, 27, 206]. This selection was based on the vast amount of literature that has shown a consistent relationship between neighbourhood environment and physical activity, as well as a causal relationship between physical activity and physical function [24, 74, 84, 199].

Guided by the literature reviewed in Chapter Two, I posited two pathways that may explain the relationship between neighbourhood disadvantage and physical function. The first pathway was through NPSC and WfR (Study Two). It was posited that advantaged and disadvantaged neighbourhoods would differ in how their residents perceived safety from crime in their neighbourhoods, and more particularly, that residents of disadvantaged neighbourhoods would be more likely to see their immediate environment as having high crime and being less safe. As a consequence, residents of disadvantaged neighbourhoods (especially women) would be less inclined to walk for recreation, and this inclination was likely to be associated with poorer physical function. The second pathway was through neighbourhood walkability and WfT (Study Three). In Brisbane, disadvantaged neighbourhoods are characterised by built environments that were more conducive to WfT [161]. Higher levels of walking are most probably beneficial for physical function; hence, it was thus hypothesised that the built environments that supported more WfT in the more disadvantaged neighbourhoods would be likely to reduce or contain inequalities in physical function between advantaged and disadvantaged neighbourhoods.

Study Two aimed to explore the contribution of NPSC and WfR in the relationship between neighbourhood disadvantage and physical function. I found that residents living in more disadvantaged neighbourhoods perceived their neighbourhoods to be less safe from crime, and undertook less WfR (among women only) than their counterparts living in more advantaged neighbourhoods. These two factors partly explained (24% in men and 25% in women) the differences in physical function between disadvantaged and advantaged neighbourhoods.

It is important to note the gender difference in some of the pathways tested. Significant relationships were found between NPSC and WfR; as well as between NPSC and physical function among women, but not men. This finding suggests that women were more ecologically vulnerable than men in that they perceived more risk and felt greater fear in response to their environment than men. This study is one of the few to have examined the role of neighbourhood social characteristics and WfR in explaining neighbourhood disadvantage and physical function. Such findings can be used to inform effective policy interventions to improve the perceptions of safety within the neighbourhoods, as well as to integrate supportive environments for physical activity to reduce inequalities in physical function.

Study Three hypothesised that the relationship between neighbourhood disadvantage and physical function was due in part to differences in neighbourhood walkability and WfT. Neighbourhood walkability was indicated by street connectivity, dwelling density, land use mix and a walkability index. When each of the pathways were tested separately, I found that disadvantaged neighbourhoods were characterised as being more dense, and more walkable, and those living in walkable neighbourhoods were more likely to walk for transport (among women only), and those who walked for transport had better physical function scores (among women only). In the absence of a supportive built environment in more disadvantaged neighbourhoods, women were less likely to walk for transport. However, when each pathway was tested simultaneously (in the fully adjusted model), the result showed no compelling evidence that the relationship between neighbourhood walkability and WfT contributed to the association between neighbourhood disadvantage and physical function. Interestingly, I found that among women, increased levels in dwelling density were associated with poorer physical function, while increased levels of land use mix were associated with better physical function. These findings have implications for the use of walkability indexes that combine street connectivity, dwelling density and land use mix in to a single exposure measure: combining the three components into one index may produce null and/or biased findings. Although neighbourhood walkability and WfT did not explain the relationship between neighbourhood disadvantage and physical function, this study highlighted that a walkable environment that supports WfT may not be sufficient to improve physical function among middle-aged to older adults.

Bringing together the findings from Study One to Three, it is understood that the neighbourhood environment is a dynamic system. As demonstrated in Chapter 4, the same neighbourhood environment does not influence everyone equally. The interplay between individual- and neighbourhood factors is complex and potentially produces heterogeneity in physical function. Even though the findings of this thesis offered some insights into neighbourhood inequalities and physical function, they only revealed a glimpse of a larger and more complex picture of social inequalities and health. Given that the two potential pathways hypothesised previously did not substantially explain neighbourhood inequalities in physical functioning among middle-aged to older adults, other unmeasured neighbourhood factors that facilitate physical activity and walking are likely to explain this relationship. These unmeasured neighbourhood factors are speculated and discussed below.

7.3.1 Social capital

Social capital, perceived at the individual-level or neighbourhood-level, has been found to be associated with health [350]. Social capital is considered a community resource and a unique fabric in the neighbourhood that builds the structure of social relationships among residents [351]. Qualitative studies have demonstrated that strong neighbourhood connectedness was particularly important to long-term residents and those who were more ‘neighbourhood-dependent’, such as the elderly and unemployed [352, 353]. High levels of social capital between residents within neighbourhoods may consequently encourage healthier behaviours. For example, neighbours may participate in more physical activity because there are increased sources of social support, companion with whom to exercise with, a greater sense of perceived security and greater exposure to health-promoting social norms to model healthier behaviour [138].

7.3.2 Quality of the built environment

Study Three showed that disadvantaged neighbourhoods had better walkability than advantaged neighbourhoods. However, walkability and its components (street connectivity, dwelling density and land use mix) do not sufficiently to capture the quality of the built environment. Neighbourhoods that are characterised as more ‘walkable’ may not necessarily have an aesthetically pleasant or well-maintained environment for walking. A recent US study has suggested that the quality of the built environment may explain why residents of more disadvantaged neighbourhoods are more likely to suffer from chronic disease related to physical inactivity [354]. Another study suggested that the poor quality of pedestrian features such as uneven footpaths or litter, can offset the benefits of living in a neighbourhoods with good walkability features [355]. Therefore, the quality of the built environment may be more important in explaining neighbourhood inequalities in physical function than simply the presence or absence of features.

7.3.3 Destinations

Destinations such as restaurants, supermarkets, shops and medical facilities within neighbourhoods may play an important role in shaping behaviour and health. Studies from the US have shown that residents of disadvantaged neighbourhoods are more likely to be exposed to unhealthy resources such as tobacco outlets, convenience stores and fast food outlets [80, 356]. The presence of unhealthy destinations in the neighbourhood, although improving walkability, may lead to poorer health. The quality of destinations in the neighbourhood is therefore likely to play an important role in how they influence physical function. Study Three used a generic land use mix measure that combined commercial, recreational, industrial, residential and other land uses. However, a measure such as this is unable to identify the actual destinations available within the neighbourhoods. Even with the same number of land uses in two neighbourhoods, the actual destinations in these neighbourhoods may be differ in terms of how they influence WfT. A study by King et al. [357] among elderly women found that transport walking is positively associated with the presence of hardware and department stores within walking distance from home, but is not positively associated with the presence of restaurants, bars or post offices. Therefore, the types of destination that matter most to transport walking among middle-aged to older adults should be a priority for future research.

7.3.4 The context of Brisbane may be different from other countries

Correspondingly, the built and social environment in Brisbane may be different from other Australian cities and countries. Unlike other Australian capital cities, neighbourhoods in Brisbane have been found to have ‘equitable differences’ in their built environment, whereby street connectivity, dwelling density and land use mix were better in the more disadvantaged neighbourhoods [161]. Conversely, although the more disadvantaged neighbourhoods were perceived as less safe from crime, a case study conducted in Brisbane found that most of its residents felt relatively safe in their neighbourhoods [358]. As a result, the variations in the NPSC between the most advantaged and the most disadvantaged neighbourhoods found in our study may be insufficient to influence physical function in a substantial way.

7.4 Strengths of the PhD thesis

The purpose of this section is to detail the strengths of the three studies, both individually, and as a whole.

7.4.1 Multilevel data and analysis

The HABITAT study is underpinned by a social ecological framework, which posits that it takes a combination of both individual- and environmental-level interventions to achieve substantial changes in health behaviours [359]. The HABITAT study collects multilevel data to simultaneously examine social, area-level and sociodemographic determinants, rather than focusing on either one determinant or one level of measurement. This is considered to be a strength of the study as it allows for the examination of area-level effects over and above individual-level effects.

7.4.2 Sample sizes

The wave 4 HABITAT data have included a very large sample size of 6,450 participants at wave 4. This large sample size enables data stratification by gender, thus facilitating a more sensitive exploration of associations and mechanisms.

7.4.3 Wide ranging, comprehensive data sources with both objective and subjective measures

The combined use of perceived and objective neighbourhood environment measures that tests relevant outcomes is a further strength of the thesis. NPSC could be more important than objective crime data in examining WfR [360, 361]. If an individual perceives their neighbourhood to be unsafe, even if it was safe (e.g., police data), it is unlikely that they will engage in recreational walking. On the other hand, transport-related walking is typically incidental and less likely to be influenced by individual perceptions and more likely to be influenced by the actual destination and design of the neighbourhood [346]. Therefore, objective measures of the built environment may be better suited to examining transport-related walking.

7.5 Limitations of the PhD thesis

This section addresses the limitations of the PhD project that may affect the generalisability and quality of the findings. When interpreting the findings of each study, consideration must be given to a number of methodological issues, including the response rate, the reliance on cross-sectional and self-reported data, potential measurement errors and misclassifications.

7.5.1 Response rate

The data used in this thesis were obtained from wave 4 of the HABITAT survey and sample attrition between baseline and wave 4 may have implications for sample generalisability. The survey non-response rate in the HABITAT baseline study was 31.5%; and non-response tended to be higher among individuals with lower SEP and residents of disadvantaged neighbourhoods. If these non-responding low SEP residents were more likely to have poorer physical function, the neighbourhood socioeconomic differences reported in the three studies are thus likely to underestimate the true magnitude of socioeconomic differences in the Brisbane population. In other words, the actual socioeconomic differences in physical function in the Brisbane populations could have been greater than what was actually observed in the studies.

7.5.2 Cross-sectional study

All three studies were cross-sectional by design as the outcome variable (physical function) was only available at one time point in the HABITAT data. Therefore, claims about causality must be made with caveats, and given the cross-sectional nature of the thesis; there are possibilities of reverse causation. For example, individuals with poorer physical function may have a lower household income because of their inability to work, and the cost of housing may mean that they select into a more disadvantaged neighbourhood. In this scenario, poorer physical function would be causing the individual to live in disadvantaged neighbourhood, rather than the neighbourhood causing the individual to have poorer physical function. Also, it is important to note that physical function may have been influenced by health behaviours and environments earlier in the life course. Several epidemiological studies [362-364] have accumulated evidence linking early life socioeconomic conditions and functional limitation in later life, suggesting that multiple exposures to unfavourable social conditions may have a larger effect on health than a single exposure at one time point. However, cross-sectional studies provide an important 'first step' for conceptual clarification, formulation of hypotheses and the examination of associations, all of which can inform potential interventions and future research.

7.5.3 Measurement error

The physical function and walking (for recreation and for transport) items were self-reported by participants. Self-reported data are often cited as being prone to bias that may lead to measurement error, which in turn can lead to under or overestimation of the contribution of the neighbourhood environment in physical function [348]. Even though the measures have been validated, the possibility of discrepancy between perception and reality is acknowledged.

i. Physical function

The physical function variable was measured using the PF-10 items from the SF-36. The self-reported PF-10 items are inexpensive, easy to collect and time efficient; but they are more likely to be biased by a myriad of factors, such as cultural background and language proficiency, which may impede comparison across populations [365, 366]. According to Seeman et al. [367], self-report measures, such as the PF-10 can discriminate low-functioning older adults (those who self-report ‘Yes, limited a lot’ in most activities) but cannot effectively discern high-functioning older adults (those who self-report ‘No, not limited at all’ in most activities) well. By contrast, performance-based measures, such as the Senior Fitness Test, are more sensitive to differences among high-functioning older adults, but perform poorly at discerning those with the lowest levels of functioning, as most tests cannot be administered to more frail subjects due to safety concerns [368]. Nevertheless, both self-report and performance-based measures of physical function are thought to capture distinct constructs, and have been shown to predict subsequent deterioration in health in diverse settings [369]. Therefore, future studies should incorporate both self-report and performance-based measures in order to comprehensively understand the complexity of physical function among middle-aged to older adults [370].

ii. Walking for recreation and walking for transport

The HABITAT mail survey assessed overall self-reported WfR and WfT in total hours or minutes over the past seven days. The walking items did not specify the setting in which the walking activity was undertaken. It is possible that the reported walking duration was undertaken outside of participants' neighbourhoods. Physical activity is a broad construct that encompasses four domains (leisure-time, transport-related, household and occupational), and the walking items used in this thesis were only able to capture the first two. It could be that participants who do not spend much time walking within their neighbourhood substitute their physical activity indoors, such as undertaking household chores [209]. Additionally, the walking items in the survey were unable to capture the intensity of the walking behaviours, which have shown to be more important to health than total walking time [193].

7.5.4 Misclassifications of neighbourhood

The concept of 'neighbourhood' is difficult to define. The conceptualisation of 'neighbourhood' in this thesis was at the CCD level, while other studies have conceptualised the neighbourhood at a smaller (a block) or larger (whole of city) aggregation, or based on individual perceptions of what constitutes a person's neighbourhood. This discrepancy in neighbourhood conceptualisation between studies makes it difficult to compare or generalise. Future studies should determine a clearer way of defining neighbourhood to generate more accurate findings [371].

7.5.5 The selected elements of social and built environment

Neighbourhood-level perception of safety from crime was the sole social environment characteristics used in this thesis. It is possible that other elements of social environment, for example, social capital, safety from traffic, social support and social cohesion, may have better explained neighbourhood inequalities in physical function. Similarly, the built environment measures used in Study Three—street connectivity, dwelling density and land use mix, do not fully represent the built environment. Therefore, assessing only selected characteristics of the social and built environment may limit our understanding on neighbourhood features that explain neighbourhood inequalities in physical function, and neighbourhood environment and health more broadly.

7.5.6 Control for confounding factors

Residual confounding by other unmeasured factors is a potential limitation. This is of particular importance in studies of neighbourhood and health, because the complex nature of interactions between people and their environment makes it difficult to control for all known confounders.

7.6 Implications of thesis findings

The thesis contributes to the neighbourhood and health research in a number of ways. First, it has establishes an understanding of neighbourhood disadvantage and physical function in the Australian context. There are many studies from the US that explored the effects of neighbourhood environment on physical function. Although it may be possible that these findings can be generalisable across setting and countries, this may not be the case for physical function, especially when it comes to understanding the mechanisms of the relationship. Understanding the mechanisms underlying this relationship may be context specific, as the neighbourhood environment in different countries could be differentially shaped by the historical, cultural and political factors. Therefore, there is a need for future studies to build on and extend the largely exploratory investigation presented here.

Second, the research findings contribute to the area of neighbourhood environment and healthy ageing. Like most developed countries, the proportion of older adults (age 65 and older) in Australia is estimated to increase to 26% by 2050 [18]. Significant contributors to Australia’s ageing population trend are the baby boomers, defined as people born between 1946 and 1964. While the majority of Australians prefer to age in place [372], understanding the neighbourhood characteristics that facilitate independence in later life is crucial in preparation for the retirement of the baby boomer generation.

Third, the gender-specific findings of the three studies highlighted the fact that men and women respond to their neighbourhood environment differently in terms of their recreation and transport walking behaviours, as well as their physical function. In the analyses presented in Studies Two and Three, gender-specific associations were observed. Many of the pathways tested were significant for women, but not men. While gender differences in the relationship between neighbourhood disadvantage and physical function was not the main focus of the thesis and thus not discussed substantially in the publications, it is worth addressing the possible reasons for the discrepancy between genders. First, women are physiologically and biologically different from men [373]. Murtagh and Hubert [261] found prominent gender differences in physical function and risk of disability. Their study found that women required more assistance with gripping and reaching, even among those who reported no difficulty in carrying out daily activities. Second, studies have suggested that gender differences in physical function are caused by women’s higher risk of mostly nonfatal but immobilising conditions [261, 374]. For example, women are much more likely to be diagnosed with depression and to suffer more from osteoarthritis than men [375, 376]. These findings suggest that gender contributes substantially to a variety of acute and chronic health conditions that affect quality of life among ageing men and women. These findings, along with the findings from this PhD, have important implications because women tend to live longer than men, and they also live longer with reduced quality of life. As a result, women may need more assistance from others and the healthcare system. Research examining physical function and other health outcomes that have apparent gender differences should thus stratify their analysis by gender.

Lastly, this thesis reveals that using a walkability index as a built environment measure may not be ideal in terms of understanding the features that matter most for physical function. Walkability has recently gained notable attention in physical activity research, and studies examining the relationship between physical activity and walkability have found consistent positive relationships across countries. In Study Three, when the components of walkability were examined separately for physical function for women, a negative relationship between dwelling density and physical function and a positive relationship between land use mix and physical function were found. These mixed findings imply that a single measure of walkability may be inappropriate for understanding physical function. In addition, a walkability index often makes it difficult to provide recommendations to policymakers on the features that are most important for maintenance of good physical function. To overcome this, the use of single built environment measures instead of a combined built environment index is recommended to understand what is most important for physical function.

7.7 Implications of thesis findings for policy, urban design and planning

This research program is funded and positioned within the *National Health and Medical Research Council (NHMRC) Centre for Research Excellence (CRE) in Healthy, Liveable,* *and Equitable Communities*. This CRE program envisioned to create places where people can be healthy and connected through the development of liveable, equitable and sustainable communities by generating evidence, thus providing planners and policy makers with a more robust basis on which to design healthy communities. The findings of this thesis have addressed several issues pertinent to international and national initiatives that are directed at improving neighbourhood environment for healthy and active ageing, as well as social inequalities in health. For example, the thesis findings are consistent with initiatives from the following:

- *World Report on Ageing and Health (2015),* World Health Organization [19]: to build an age-friendly world through increasing perceptions of safety within their neighbourhoods; to create environments that encourage physical activity and to reduce built environment barriers to facilitate mobility.
- *Blueprint for an Active Australia (2014),* National Heart Foundation of Australia [336]: to design neighbourhood environments that increases daily physical activity levels through recreational and transport-related walking and cycling (Action area 1); to implement policies and interventions that facilitate the uptake of active travel (Action area 4); to address inequality in physical activity participation among disadvantaged populations (Action area 7); and to plan and retrofit environments to promote more walking opportunities for the ageing population (Action area 10).
- *Seniors' Strategy 2012-2017: Delivering a Seniors-Friendly City,* Brisbane City Council [377]: to design an active, healthy city by promoting wellbeing through active lifestyle choices and provision of health and home-care services (Priority 2); to build an accessible connected city by improving transport options in the local community (Priority 3); and to create a well-designed city to support 'ageing

in place’ by optimising safety and accessibility and offering senior-friendly public open space equipped with park benches and street furniture (Priority 4).

- *Active Ageing: A Policy Framework (2002)*, World Health Organization [276]: to reduce disability rates associated with chronic diseases among the ageing population; to understand the determinants of active ageing; to add more quality of life in years as the population grows older, to reduce medical and healthcare cost; and to increase participation in physical activity across socioeconomic groups.

Consistent with the social ecological framework, this thesis has identified multiple levels of factors that contribute to neighbourhood inequalities in physical function. These findings are important, as they can effectively guide research translation. For example, in Study Two, I found that neighbourhoods perceived to be less safe from crime were associated with lower levels of WfR, which in turn, were associated with poorer physical function. Improving perceptions of safety from crime in the neighbourhoods through enhancement of street surveillance or repairing vandalised buildings may help residents feel safer when WfR. On the other hand, even though the findings from Study Three suggested that neighbourhood walkability and WfT did not explain the relationship between neighbourhood disadvantage and physical function, I found that more disadvantaged neighbourhoods in Brisbane were characterised by higher walkability scores that were associated with more WfT. Walking is beneficial for health, and numerous studies have shown that it is never too late to initiate physical activity, even among people with chronic diseases and old age [378, 379]. This finding provides important information for local policy makers, urban planners, transport planners, as well as industry and community groups to make targeted changes (e.g., making places safe and interesting to walk, increasing street connectivity and enacting a more diverse mix of land use) to increase walking for all residents.

7.8 Future research

7.8.1 Longitudinal design

It is increasingly recognised that neighbourhoods are not static, as they change and progress dynamically through time [380]. Where possible, longitudinal design or natural experiments (where participants move from one neighbourhood to another) can provide a more appropriate design for examining the causal effects of neighbourhoods on health [345, 381]. Longitudinal studies of neighbourhood disadvantage and physical function are capable of examining changes in the exposure on levels of neighbourhood disadvantage, along with changes in physical function [333]. As populations continue to grow, increasing new developments and initiatives to revitalise or modify existing suburbs present valuable natural experiment opportunities. Natural experiment studies are capable of measuring the amount of change in the level of neighbourhood disadvantage exposure needed to prevent within-individual physical function decline [345, 381]. Such study designs will automatically control for unobserved confounding for individual-level covariates that do not change over time [382].

7.8.2 Social circumstances across the life course

According to Wheaton and Clarke [383], understanding neighbourhood effects on health without considering the social circumstances that occur across the life course represents a blind spot in the empirical literature on neighbourhood effects. The life course approach to chronic disease epidemiology is defined as “the study of long-term effects on chronic disease risk of physical and social exposures during gestation, childhood, adolescence, young adulthood and later adult life". [371]. The study of neighbourhood reveals a clear awareness of the persistent effects of context on the influence of concentrated poverty in neighbourhoods. In this perspective, the neighbourhood, as a form of social context and bounded micro-social system, sets hopes and expectations, defines differential opportunity structures, and thereby stabilizes inequality.

7.8.3 Qualitative studies

There is growing acknowledgement of using both qualitative and quantitative techniques as a complementary and synergistic approach in research methods. Using qualitative or quantitative techniques on its own are limited in understanding the broader picture of the research question [384]. Of particular relevance to this thesis is that qualitative research techniques can contribute to the development of more theoretically-based and valid measurement instruments because they enable the researcher to clarify issues of terminology and interpretation for the target group. For example, the term 'neighbourhood' can be clarified and understood in order to produce more accurate findings. Conversely, quantitative methods can ascertain whether conclusions derived from qualitative research are consistent with quantitative results, thus allowing cross-verifications between findings.

7.9 Concluding remarks

Given the ageing of the Australian population, an important public health goal is to ensure healthy and successful ageing: maintenance of good physical function, remaining active for as long as possible and ensuring morbidity compression. This thesis concludes that the neighbourhood environment in which we live is important to physical function, especially for women. To reduce neighbourhood inequalities in physical function, attention needs to be given to improve the perceptions of safety in more disadvantaged neighbourhoods to encourage more walking for recreation, which is beneficial for physical function. Living in a walkable neighbourhood is important to support more walking for transport, but may not be sufficient to reduce neighbourhood inequalities in physical function. Despite the complexity in understanding neighbourhood socioeconomic differences in physical function, this thesis has provided valuable information to implement effective strategies for reducing neighbourhood inequalities in physical function. More research in this area is needed to further unpack the possible dimensions of neighbourhood influences on physical function to keep pace with demographic changes, and to support a healthy, liveable and equitable community for healthy ageing.

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APPENDIX I: RESEARCH PORTFOLIO

Publication for Study One (Chapter 4)

In the case of Study One, the nature and contribution to the work 'Neighbourhood disadvantage, individual-level socioeconomic position and physical function: a cross-sectional multilevel analysis' was the following:

	Name	**Nature of contribution**	**Extent of contribution (%)**	**Signature**
1	**Venurs HY Loh**	Critical literature review and development of research questions, data preparation, analysis design, statistical analysis, interpretation of results, tables, writing of manuscript, submission to journal, accepts overall responsibility for the publication	55	
2	**Jerome N Rachele**	Assisted with design of analysis and interpretation of results, commented on manuscript drafts	10	
3	**Wendy J Brown**	Designed and conducted the HABITAT study, facilitated development of research question, assisted with interpretation of results and commented on manuscript drafts	10	Wendy Brown
4	**Simon Washington**	Commented on manuscript drafts	5	
5	**Gavin Turrell**	Designed and conducted the HABITAT study, facilitated development of research question, assisted with design of analysis and commented on manuscript drafts	20	

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Neighborhood disadvantage, individual-level socioeconomic position and physical function: A cross-sectional multilevel analysis

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ABSTRACT

Introduction. Understanding associations between physical function and neighborhood disadvantage may provide insights into which interventions might best contribute to reducing socioeconomic inequalities in health. This study examines associations between neighborhood-disadvantage, individual-level socioeconomic position (SEP) and physical function from a multilevel perspective.

Methods. Data were obtained from the HABITAT multilevel longitudinal (2007-13) study of middle-aged adults, using data from the fourth wave (2013). This investigation included 6004 residents (age 46–71 years) of 535 neighborhoods in Brisbane, Australia. Physical function was measured using the PF-10 (0–100), with higher scores indicating better function. The data were analyzed using multilevel linear regression and were extended to test for cross-level interactions by including interaction terms for different combinations of SEP (education, occupation, household income) and neighborhood disadvantage on physical function.

Results. Residents of the most disadvantaged neighborhoods reported significantly lower physical function (men: β −11.36 95% CI −13.74, −8.99; women: β −11.41 95% CI −13.60, −9.22). These associations remained after adjustment for individual-level SEP. Individuals with no post-school education, those permanently unable to work, and members of the lowest household income had significantly poorer physical function. Cross-level interactions suggested that the relationship between household income and physical function is different across levels of neighborhood disadvantage for men; and for education and occupation for women.

Conclusion. Living in a disadvantaged neighborhood was negatively associated with physical function after adjustment for individual-level SEP. These results may assist in the development of policy-relevant targeted interventions to delay the rate of physical function decline at a community-level.

1. Introduction

Physical function is defined as difficulty in performing activities that require physical capacity, ranging from activities of daily living (e.g., housework, shopping, walking and climbing stairs) to more vigorous activities that require increasing degrees of mobility, strength or endurance (Bruce et al., 2009). Difficulty with physical function, represented by the inability to perform usual activities of everyday life, is a serious problem among older persons (Beckett et al., 1996; Payette et al., 2011; Glass & Balfour, 2003). The magnitude of this problem is likely to become considerably greater with continuing increases in longevity and in the size of the oldest population in most developed countries (Beckett et al., 1996; Fries, 2002). In addition, physical function is associated with an increased risk of falling, cognitive decline and all-cause mortality (Beckett et al., 1996).

According to the World Health Organization (2002), the rate of physical function decline is not typically the result of a single cause, but arises from an interaction of risk factors in various domains, both individual and environmental. Traditionally, research on the determinants of physical function has been based on individual-level factors (Lang et al., 2008; Lunney et al., 2003; Keating et al., 2005; LaCroix et al., 1993a). More recently, interest in the effects of neighborhood context on physical health has received growing attention; and multiple studies have shown that poor health is partly a function of residing in socioeconomically disadvantaged areas (Diez Roux, 2001; Diez Roux

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et al., 2001; Pickett & Pearl, 2001). Research suggests that the external environment, such as the neighborhood, is of particular importance for physical function in older adults as they tend to have a longer duration of exposure to neighborhood influences than younger individuals, possibly due to retirement (Kawachi & Berkman, 2003). Older adults are also a sub-group with declining physical and mental health, shrinking social networks, loss of social support and increased fragility that may reduce their ability to cope with environmental demands (Kawachi & Berkman, 2003). It is possible that heterogeneity in physical function among this group may be explained by both individual- and neighborhood-level factors, underlining the importance of any associations between physical function and neighborhood characteristics (Balfour & Kaplan, 2002).

Several studies (three single-level and one multilevel) (Wight et al., 2008; Glymour et al., 2010; Feldman & Steptoe, 2004; Beard et al., 2009) have examined the association between neighborhood disadvantage and physical function. Findings from these studies are mixed. Among the single-level studies, one (Glymour et al., 2010) found no association between neighborhood disadvantage and physical function, while the other two (Feldman & Steptoe, 2004; Beard et al., 2009) showed that residents of socioeconomically disadvantaged neighborhoods exhibited lower function than their counterparts from more advantaged neighborhoods. However, these two ecological studies used data that were aggregated to a single geographical scale, hence they couldn't provide a quantification of the variation between areas, or show whether and how much of the variation was due to the clustering of individuals (a compositional effect) or the environmental characteristics of the areas (a contextual effect). Given the lack of multilevel studies, the question of whether the neighborhood socioeconomic environment influences physical function after adjustment for individual-level socioeconomic position (SEP) remains. The only known multilevel study of neighborhood disadvantage and physical function (Wight et al., 2008) found no significant association between these factors; and whilst this work provided an important advancement in this field, the study assumed a uniform effect of the neighborhood environment across individual-level SEP. It is possible however that the socioeconomic context of the neighborhood environment may affect people differently even if they have similar individual-level socioeconomic characteristics. For example, an individual with low educational attainment living in a more advantaged neighborhood might have better physical function than an individual with the same educational attainment living in a more disadvantaged neighborhood. This may be due to the benefit of the collective material and social resources in their neighborhood, such as services, job opportunities and social support (Yen & Kaplan, 1999; Macintyre et al., 2002; Stafford & Marmot, 2003).

This cross-sectional study investigates associations between neighborhood disadvantage, individual-level SEP, and self-reported physical function; and further examines whether the relationship between individual-level SEP and physical function differs by level of neighborhood disadvantage. It is hypothesized that those residing in more disadvantaged neighborhoods and those from lower socioeconomic groups will exhibit poorer physical function than their counterparts from more advantaged backgrounds.

2. Methods

This study received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3967H & 1300000161).

2.1. Study population

Data were obtained from the **H**ow **A**reas in **B**risbane **I**nfluence Heal**T**h and **A**c**T**ivity (HABITAT) multilevel longitudinal (2007–13) study in Brisbane, Australia. Brisbane is the capital city of the state of Queensland, and the third largest city in Australia with a population of approximately 2.3 million (Australian Bureau of Statistics, 2015a) and a median age of 35 in 2014 (Australian Bureau of Statistics, 2015b). The average disposable income of Brisbane population was AU$52,000 per annum in 2011 (Australian Bureau of Statistics, 2013a).

Details about HABITAT's baseline sampling design have been published elsewhere (Burton et al., 2009). Briefly, a multi-stage probability sampling design was used to select a stratified random sample ($n = 200$) of Census Collector's Districts (CCD) in 2007, and from within each CCD, a random sample of people (on average 85 per CCD) aged 40–65 years. However, as participants moved to new residences over time, the number of CCDs increased to 535 in 2013.

The primary area-level unit-of-analysis for the HABITAT study is the CCD (hereafter referred to as 'neighborhoods'). At the time the study commenced in 2007, these were the smallest administrative units used by the Australian Bureau of Statistics (ABS) to collect census data, and contain an average of 200 private dwellings.

2.2. Data collection and response rates

A structured self-administered questionnaire was developed that asked respondents about their neighborhood; participation in physical activity; correlates of activity, health and well-being; and socio-demographic characteristics. The questionnaire was sent to sampled residents during May–July in 2007, 2009, 2011 and 2013 using the mail survey method developed by Dillman (2000). After excluding out-of-scope respondents (i.e., deceased, no longer at the address, unable to participate for health-related reasons), the total number of usable surveys returned in each survey wave was 11,035 (68.3% response), 7866 (72.3% response from eligible and contactable participants), 6900 (66.7% response from eligible and contactable participants) and 6520 (69.3% response from eligible and contactable participants), respectively.

2.3. Measures

Neighborhood socioeconomic disadvantage: the neighborhood socioeconomic disadvantage measure was derived using weighted linear regression, using scores from the ABS' Index of Relative Socioeconomic Disadvantage (IRSD) from each of the previous six censuses from 1986 to 2011 (Australian Bureau of Statistics, 2013b). A neighborhood's IRSD score reflects each area's overall level of disadvantage measured on the basis of 17 socioeconomic attributes, including: education, occupation, income, unemployment, household structure and household tenure. HABITAT's original sample of neighborhoods was stratified by area-level socioeconomic disadvantage using the 2001 Census boundaries (the Census in Australia is every 5 years). This method honors the original geographic structure from the baseline sample, while also accommodating for the changes in area boundaries used by the ABS prior to 2011, changes in area-level sampling units at the 2011 Census, and changes in socioeconomic disadvantage over time. The derived socioeconomic scores from each of the HABITAT neighborhoods ($n = 535$ in 2013) were then grouped into quintiles based on their IRSD scores with Q1 denoting the 20% most advantaged areas relative to the whole of Brisbane and Q5 the most disadvantaged 20%.

2.4. Education

Respondents were asked to provide information about their highest education qualification completed using a nine-category measure that was subsequently coded as (i) Bachelor degree or higher (the latter included postgraduate diplomat, master's degree, or doctorate), (ii) Diploma (associate or undergraduate), (iii) Vocational (trade or business certificate or apprenticeship), and (iv) No post-secondary school qualification.

2.5. Occupation

Respondents who were employed at the time of completing the survey were asked to indicate their job title and then to describe the main tasks or duties they performed. This information was subsequently coded to the Australian Standard Classification of Occupations (ASCO) (Australian Bureau of Statistics, 1997). The ASCO is a skill-based measure that groups occupations according to levels of knowledge required, tools and equipment used, materials worked on, and goods and services produced. The occupational groupings are hierarchically ordered based on the relative skill levels across these different dimensions, with those occupations having the most extensive skill requirements located at the top of the hierarchy. For the purpose of this study, the original 9-level ASCO classification was recoded into 3 categories: (i) Managers/professionals, (ii) White-collar employees, and (iii) Blue-collar employees. Respondents who were not employed were categorized as follows: (iv) Home duties, (v) Retired, (vi) Permanently unable to work, and (vii) Missing/NEC (unemployed, students or other classifiable (not easily classifiable)).

2.6. Household income

Respondents were asked to indicate their total annual household income using a 14-category measure that was subsequently recoded into 6 groups for analysis: (i) AU$130,000 or more, (ii) AU$72,800–129,999, (iii) AU$41,600–72,799, (iv) AU$26,000–41,599, (v), Less than AU$25,999, and (vi) Missing.

2.7. Self-reported physical function

This was measured using the Physical Function Scale (PF-10), a component of the Short Form-36 (SF-36) Health Survey (Ware et al., 1994). The PF-10 was first included in the most recent wave of HABITAT survey (2013), so only cross-sectional analyses were possible at the time analysis was conducted. The stem-question of the PF-10 asks: "Does your health now limit you in these activities? If so, how much?" Respondents were asked to indicate: "Yes, limited a lot" or "yes, limited a little" or "no, not limited at all' for each activity. The PF-10 measures a hierarchical range of difficulties, from vigorous activities such as lifting heavy objects to everyday activities such as bathing and dressing (Haley et al., 1994). This measure has been extensively validated among community-dwelling adults using convergent validity calculated by Pearson Correlations using 3-performance based measures: single limb stance as an indicator of balance ($r = 0.42$), Time Up and Go test as a measure of mobility ($r = -0.70$) and gait speed as an indicator of overall functional capacity ($r = 0.75$) (Bohannon & DePasquale, 2009). The method of data cleaning for the physical function score was adapted from Ware and colleagues (Ware et al., 1994). The raw physical function scores were calculated as the sum of (re-coded) scale items and transformed to a 0 to 100 scale according to Eq. (1):

$$\text{Physical function score} = \frac{\text{raw score} - \text{minimum possible raw score}}{\text{possible raw score range}} \times 100 \quad (1)$$

A standard scoring system was used such that 0 represents minimal functioning and 100 represents maximal functioning. The scale used for this present study obtained high test–retest reliability (Cronbach's $\alpha = 0.89$) in the sample. Although scores were somewhat negatively skewed toward maximal function, they are comparable with Australian population norms for this scale (age standardized mean = 83.6 for men and 81.5 for women) (Australian Bureau of Statistics, 1995).

2.8. Statistical analysis

Participants who moved out of Brisbane in 2013 ($n = 391$) or had missing data for physical function ($n = 92$), sex ($n = 19$) or education ($n = 14$) were excluded. This reduced the analytic sample to $n = 6004$ (92.1% of the total sample). Characteristics and physical function profile of the analytic sample are presented in Table 1.

A directed acyclic graph (DAG) was constructed to show contextual and/or temporal relationships between the socioeconomic indicators education, occupation, household income, neighborhood disadvantage, and physical function (Fig. 1). The DAG formed the basis for the modeling strategy and specified the socioeconomic independent adjustment variables. As presented in Fig. 1, education was conceptualized as a common prior cause of occupation, household income and neighborhood disadvantage; occupation as a confounder of income and neighborhood disadvantage, and household income as a confounder of neighborhood disadvantage. The analyses were stratified by gender as physical function score differs for men and women (women consistently report more functional limitations than men) (Beckett et al., 1996; Leveille et al., 2000; Oman et al., 1999).

Multilevel modeling is the appropriate statistical technique for these analyses as it offers a robust and efficient approach to the examination of hierarchical data where individuals are nested (clustered) within neighborhoods (Tom et al., 1999). Multilevel linear regression was undertaken in the following stages: Model 1) neighborhood disadvantage and physical function adjusted for age; Model 2) neighborhood disadvantage and physical function adjusted for age and individual-level SEP. Additional models were then undertaken for individual-level SEP; Model 3) education adjusted for age; Model 4) occupation adjusted for age and education; and Model 5) household income adjusted for age, education and occupation. A Variance Partition Coefficient (VPC) was calculated to estimate the percentage of total variance in physical function between neighborhoods (Goldstein et al., 2002). For Models 1 and 2, the VPC was calculated by dividing the between neighborhood variance by the total variance, and is interpreted as the proportion of total residual variation that is due to differences between neighborhoods. The analysis was extended to test for cross-level interactions by including interaction terms for different combinations of individual-level SEP and neighborhood disadvantage on physical function score. The substantive focus of the interaction analyses is on whether associations between education, occupation, and household income differed across neighborhoods that varied in their level of socioeconomic disadvantage. The fit of interaction models was assessed using a deviance test (Rasbash et al., 2014) (alpha set at 0.05). Models 1–5 were analyzed with STATA 13.1 (Stata Statistical Software: Release 13, 2013) using the *runMLwiN* command, (Leckie & Charlton, 2013) while cross-level interaction models were analyzed using MLwiN v.2.30 (Rasbash et al., 2014).

3. Results

The mean for physical function scores for neighborhood disadvantage, age, education, occupation and household income are presented in Table 1. Mean physical function were lowest for women, those aged 66–71, residents of the most disadvantaged neighborhoods, the least educated, those who were permanently unable to work, and members of the lowest income households.

The associations between neighborhood disadvantage, individual-level SEP and physical function for men and women are shown in Table 2.

For men, there was no significant between-neighborhood variation in physical function in either the age-adjusted (Model 1, $p = 0.48$) or fully-adjusted models (Model 2, $p = 0.56$). Men living in more disadvantaged neighborhoods (Q3, Q4 and Q5) had lower physical function scores than their counterparts residing in more advantaged neighborhoods. These associations remained significant after adjustment for

Table 1
Mean physical function (PF) scores (95% CI) for the socio-demographic variables used in the analysis[a].

N = 6004	Men			Women		
	N (%)	Mean PF score	95% CI	N (%)	Mean PF score	95% CI
Total sample	2551	87.6	86.9, 88.3	3453	83.7	83.0, 84.4
Age						
46–50	571 (22.4)	92.2	91.0, 93.3	670 (19.4)	90.1	88.9, 91.3
51–55	551 (21.6)	88.9	87.6, 90.4	742 (21.5)	86.3	84.9, 87.7
56–60	520 (20.4)	86.8	85.3, 88.4	718 (20.8)	84.7	83.4, 86.0
61–65	488 (19.1)	85.5	83.8, 87.2	686 (19.9)	80.9	79.3, 82.5
66–71	421 (16.5)	83.2	81.4, 85.0	637 (18.4)	75.5	73.7, 77.3
Neighborhood disadvantage						
Q1 (most advantaged)	543 (21.3)	91.8	90.7, 92.9	734 (21.3)	88.1	86.9, 89.2
Q2	680 (26.7)	90.0	88.9, 91.1	907 (26.3)	85.9	84.8, 87.1
Q3	516 (20.2)	87.3	85.8, 88.7	664 (19.2)	83.7	82.2, 85.2
Q4	466 (18.3)	85.3	83.6, 87.1	656 (19.0)	81.4	79.8, 82.9
Q5 (most disadvantaged)	346 (13.5)	80.1	77.5, 82.6	492 (14.2)	76.1	73.8, 78.4
Education level						
Bachelor degree or higher	930 (36.5)	90.9	90.0, 91.8	1156 (33.5)	86.8	85.7, 87.7
Diploma	312 (12.2)	89.4	87.9, 91.0	398 (11.5)	84.3	82.3, 85.7
Vocational	533 (20.9)	86.4	84.7, 88.1	499 (14.5)	84.0	82.3, 85.7
No post school qualifications	776 (30.4)	83.9	82.4, 85.3	1400 (40.5)	80.9	79.8, 82.0
Occupation						
Manager/professionals	928 (36.4)	91.7	90.9, 92.6	1042 (30.2)	89.6	88.7, 90.5
White collar	328 (12.9)	90.7	89.3, 92.1	870 (25.2)	86.9	85.8, 87.9
Blue collar	485 (19.0)	88.1	86.6, 89.6	162 (4.7)	86.5	83.9, 89.1
Home duties	18 (0.7)	83.3	71.8, 94.8	277 (8.0)	83.3	80.9, 85.7
Retired	510 (20.0)	82.7	81.1, 84.5	784 (22.7)	76.4	74.8, 78.0
Permanently unable to work	57 (2.2)	56.3	48.8, 63.8	62 (1.8)	38.5	30.9, 46.0
Missing/NEC	225 (8.8)	84.3	81.3, 87.3	256 (7.4)	80.2	77.6, 82.8
Household income						
$130,000 or more	676 (26.5)	92.5	91.6, 93.4	589 (17.0)	90.9	89.8, 92.0
$72,800–129,999	631 (24.7)	89.8	88.7, 90.9	794 (23.0)	87.0	85.7, 88.1
$41,600–72,799	328 (12.9)	87.8	86.0, 89.5	398 (11.5)	84.1	82.2, 85.9
$26,000–41,599	438 (17.2)	83.6	81.8, 85.5	665 (19.3)	79.1	77.5, 80.7
Less than $25,999	216 (8.5)	73.6	70.0, 77.2	391 (11.3)	73.6	71.2, 76.0
Missing	262 (10.2)	87.7	85.5, 89.9	619 (17.9)	83.7	81.9, 85.3

[a] Unadjusted data.

individual-level SEP, despite slight attenuation. Compared to individuals with a bachelor degree or higher, individuals who had no post-school education, or a vocational level of educational attainment had a significantly lower physical function score. Individuals who were retired and permanently unable to work had significantly lower physical function scores than managers and professionals, while individuals in the lower income categories ($26,000–41,599 and <$25,999) had significantly lower physical function than their counterparts with incomes of $130,000 or greater.

Similarly for women, there was no significant between-neighborhood variation in physical function for either age-adjusted (Model 1) or fully-adjusted models (Model 2). Women living in more disadvantaged neighborhoods (Q2, Q3, Q4 and Q5) had a significantly lower physical function score than their counterparts residing in more advantaged neighborhoods. These associations remained significant after adjustment for individual-level SEP, despite slight attenuation. Compared to individuals with a bachelor degree or higher, individuals who had no post-school education had a significantly lower physical function score. Individuals working as home duties, retired and permanently unable to work had significantly lower physical function scores than managers and professionals, while individuals in the lower income categories ($72,800–129,999, $41,600–72,799, $26,000–41,599 and <$25,999) had significantly lower physical function scores than their counterparts with incomes of $130,000 or greater.

Other than the significant results demonstrated, it is important to note the magnitude of difference in physical function score in men and women. A previous review found a three point difference in physical function score measured by the SF-36 to be clinically meaningful for effective intervention (Bize et al., 2007). Education attainment and household income appear to be more important, in terms of physical function, in men than women. Men with the lowest education attainment appear to have lower physical function scores (2 points) than women, after adjusting for age. Similarly, men with the lowest household income had physical function scores that were 4 points lower than low income women. On average, men and women who reported being permanently unable to work had very low physical function scores (<60), but the magnitude of difference between men and women in this group was notable. Women who reported being permanently unable to work, had, on average, a physical function score that was 17 points lower than men.

Cross-level interactions were not significant between neighborhood disadvantage and education and occupation among men; and neighborhood disadvantage and household income among women. However, a significantly better model fit was found between neighborhood disadvantage and household income among men ($p = 0.004$); and neighborhood disadvantage and education ($p = 0.01$) and occupation ($p < 0.001$) among women (Fig. 2).

4. Discussion

This study examined associations between neighborhood disadvantage, individual SEP and physical function. Significant and graded associations were found between neighborhood disadvantage and physical function for both men and women, after adjusting for individual level SEP, suggesting that the socioeconomic characteristics of the neighborhood environment may have important implications for physical function. The cross-level interaction models suggested that there was a protective effect of living in more socioeconomically advantaged neighborhoods on physical function. The findings of this study are consistent with previous single-level studies conducted in the United States and the United Kingdom (Feldman & Steptoe, 2004; Beard et al., 2009), which found that individuals living in more disadvantaged neighborhoods experienced poorer physical function than those in more advantaged neighborhoods. However, the only previous multilevel study (Wight et al., 2008) from the United States found no association between neighborhood disadvantage and physical function, after adjusting for individual-level factors. There are a number of possible explanations for the differences found between our study and those of Wight et al. (2008): including the sample age at the time at which data was collected, differences in the method of calculating area-level disadvantage, and geographical differences in the sampling of participants.

Consistent with prior research, men in our study were more likely to report better physical functioning than women (Murtagh & Hubert, 2004; Kandrack et al., 1991; Verbrugge & Wingard, 1987). The magnitude of difference in physical function score between men and women was notable in this study. Although this may due to the well-documented gender-based reporting bias on physical function (Louie & Ward, 2010), it is also possible that this discrepancy could be attributed to the differences in biology, control over resources and their decision making power in family and community, as well as the roles and responsibilities that society assigns to them (Östlin et al., 2006).

Individuals in this study with higher levels of educational attainment, individuals with a higher level of occupation, and members of high income households reported higher physical function. Previous studies have shown that income and education are likely to be closely linked, but with one influencing the other via distinct aetiological pathways (Brennan & Turrell, 2012; Turrell et al., 2007). Educational attainment for example, may influence the acquisition of knowledge about appropriate health practices, which may facilitate or constrain one's ability to maintain good physical function; whereas household income is likely to reflect the availability of resources to access health facilities and services (Brennan & Turrell, 2012; Kelleher, 2002).

This investigation is the first-known study to examine cross-level interactions between neighborhood disadvantage, individual-level SEP and physical function. These models revealed that associations between individual socioeconomic indicators differed across levels of neighborhood disadvantage. This finding brings to light interesting trends for how individuals with the same individual-level characteristics fared while residing in disadvantaged neighborhoods, when compared with their counterparts in more advantaged neighborhoods. For example, participants with the lowest education attainment living in the most disadvantaged neighborhoods were observed to have the lowest physical function score, signifying double disadvantage. Double disadvantage has also been reported in other social epidemiological studies (McPhedran, 2010; De Jong & Madamba, 2001; Gething, 1997). For instance, people with disability who live outside major cities may fare worse than their counterparts living in major cities, or people with no disability who live outside major cities (McPhedran, 2010). These findings suggest that while individual- and neighborhood-level socioeconomic disadvantage may affect physical function independently, they also interact with one another to impact physical function in a collective way. Therefore, living in a socioeconomically advantaged neighborhood or having higher SEP attributes alone may not be enough to ensure better physical function.

The neighborhood environment has emerged as an important context for health, by either facilitating healthy behavior, or acting as a barrier (Kawachi & Berkman, 2003). A number of possible mechanisms may explain the significant associations found in our study. According to Ross and colleagues (Ross & Mirowsky, 2001), the lack of economic and social resources in disadvantaged neighborhoods predisposes residents to physical and social ailments due to limited opportunity, and lack of social integration and cohesion. Characteristics of disadvantaged neighborhoods exist in both physical (e.g., lack of proper parks, health services, and tree coverage) and social forms (e.g., crime, public smoking or drinking, and conflicts). For example, Balfour and Kaplan (2002) reported that neighborhoods with multiple physical barriers such as poor access to public transport, inadequate lighting, trash and litter might trigger a pattern of disuse and subsequent decrements in functional health. On the other hand, neighborhoods with an adverse social climate may discourage social ties between neighbors that may influence behavior in ways that produce negative health outcomes

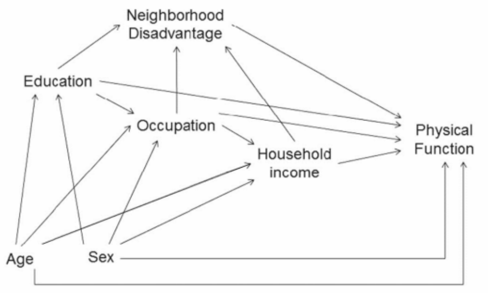

Fig. 1. Directed acyclic graph conceptualizing the relationships between neighborhood disadvantage, individual-level SEP and physical function.

(Baum, 1999; Evans et al., 1994). For example, neighborhoods with greater social ties have higher levels of involvement in community activities, enabling residents to share 'norms' that influence health behaviors such as healthy eating and physical activity, both of which are important in the maintenance of physical function (Spanier & Allison, 2000; Wendel-Vos et al., 2007). Also, the physical and social characteristics that exist in disadvantaged neighborhoods may influence physical function through different pathways such as physical activity (Wendel-Vos et al., 2007; He & Baker, 2004; Manini & Pahor, 2009) diet (Demark-Wahnefried et al., 2004), and smoking (LaCroix et al., 1993b; Nelson et al., 1994). Several studies have suggested that particular neighborhood features, including the presence of parks, recreational facilities, sidewalks and pleasant landscaping may promote physical activity among older adults (Frank et al., 2010; Berke et al., 2007; Li et al., 2008). While the lack of access to health food stores and the social norm of smoking in the neighborhood are associated with poorer diet (Krukowski et al., 2010) and smoking behavior (Turrell et al., 2012), respectively. Therefore, living in a disadvantaged neighborhood may not provide the environmental support for individual lifestyle behaviors that are needed to maintain good physical function.

4.1. Limitations

Several methodological and analytical issues need to be considered when interpreting and understanding this study's findings. First, the study is cross-sectional and thus, claims about causality must be made with caveats. A longitudinal design would have added strength to the study findings. Second, the study data were obtained from the fourth wave of the HABITAT survey and sample attrition between baseline and 2013 may have implications for sample generalizability. The non-response rate in the HABITAT baseline study was 31.5%, and a comparison of the HABITAT baseline respondent sample with census data indicates an under-representation of men, those not in the workforce, those with low household income and those living in disadvantaged area (Turrell et al., 2014). Previous studies show that low SEP groups and residents of more deprived neighborhoods are least likely to participate in survey research (Turrell et al., 2003; Kavanagh et al., 2005). As a result, the socioeconomic variation in the sample is likely to be less than that in the Brisbane population. Hence, it is likely that our results underestimate the 'true' magnitude of neighborhood disadvantage on physical function. Third, the findings of this study may also be confounded by unobserved individual and neighborhood-level factors, such as social capital, or biased from the misclassification of self-reported responses. Fourth, the between neighborhood variance for Models 1 and 2 in women was estimated as zero. Even though this 'null finding' suggests that neighborhoods do not influence self-reports of physical function,

Table 2
Multilevel linear regression for the association between neighborhood disadvantage and individual-level socioeconomic position on physical function in men and women in Brisbane.

N = 535 neighborhoods	Men (n = 2551)		Women (n = 3453)	
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Neighborhood-level				
Disadvantage	Model 1	Model 2	Model 1	Model 2
Q1 (most advantaged)[a]	1.00	1.00	1.00	1.00
Q2	−1.89 (−3.89, 0.10)	−0.74 (−2.67, 1.18)	−1.92 (−3.78, −0.06)	−1.57 (−3.38, 0.23)
Q3	−4.19 (−6.32, −2.06)	−2.69 (−4.78, −0.60)	−3.85 (−5.86, −1.84)	−2.22 (−4.19, −0.23)
Q4	−6.28 (−8.45, −4.11)	−4.36 (−6.53, −2.19)	−5.86 (−7.87, −3.85)	−3.85 (−5.86, −1.83)
Q5 (most disadvantaged)	−11.36 (−13.74, −8.99)	−7.14 (−9.54, −4.73)	−11.41 (−13.60, −9.22)	−8.79 (−11.00, −6.59)
Between neighborhood variance (SE)[b]	1.79 (2.47)	1.33 (2.25)	0 (0)	0 (0)
Between individual variance (SE)[c]	285.36 (8.31)	255.92 (7.71)	358.97 (8.71)	315.15 (7.65)
VPC (%)[d]	0.62	0.53	0	0
Individual-level				
Education		Model 3		Model 3
Bachelor degree or higher[a]		1.00		1.00
Diploma		−0.88 (−3.08, 1.31)		−1.48 (−3.68, 0.71)
Vocational		−3.68 (−5.53, −1.84)		−1.83 (−3.87, 0.21)
No post-school qualifications		−5.93 (−7.59, −4.27)		−3.78 (−5.32, −2.25)
Occupation		Model 4		Model 4
Manager/professional[a]		1.00		1.00
White collar		0.52 (−1.62, 2.66)		−1.39 (−3.19, 0.40)
Blue collar		−0.96 (−2.95, 1.03)		−1.22 (−4.33, 1.88)
Home duties		−7.04 (−14.65, 0.57)		−4.16 (−6.68, −1.63)
Retired		−5.13 (−7.34, −2.93)		−7.96 (−10.06, −5.85)
Permanently unable to work		−32.21 (−36.68, −27.73)		−48.99 (−53.79, −44.2)
Household income		Model 5		
$130,000 +[a]		1.00		
$72,800–129,999		−1.41 (−3.23, 0.41)		
$41,600–72,799		−2.22 (−4.51, 0.06)		
$26,000–41,599		−4.07 (−6.36, −1.78)		
Less than $25,999		−10.19 (−13.07, −7.30)		

Note. PF score range from 0 to 100; <0.05; missing category is included in the analysis but not reported in the table. Model 1: age and neighborhood disadvantage; Model 2: Model 1 and education, occupation and household income; Model 3: education and, age; Model 4: Model 3 and occupation; Model 5: Model 4 and household income.

[a] Reference group.

[b] Variance Partition Component (VPC) = b/(b + c).

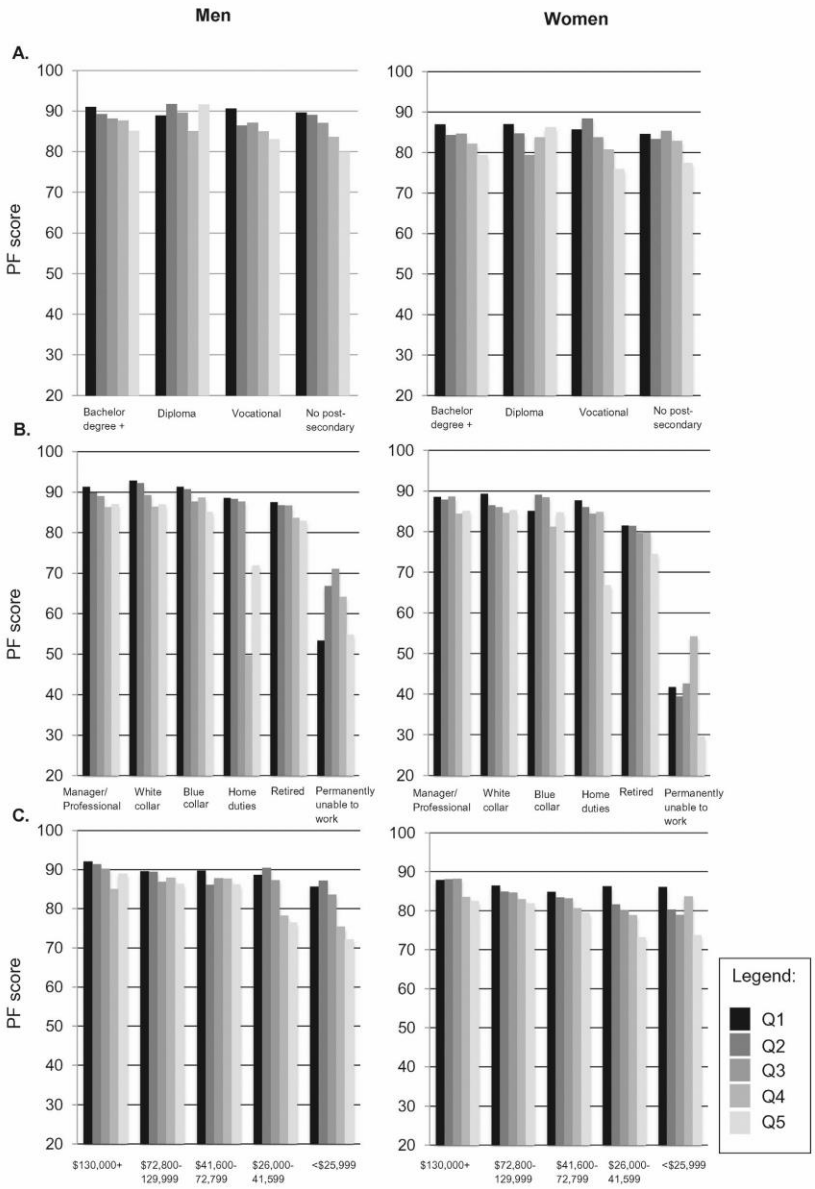

Fig. 2. Cross-level interactions and mean physical function score between neighborhood disadvantage and A. education, B. occupation and C. household income. Q1 – most advantaged and Q5 – most disadvantaged neighborhoods.

this might be due to the study's statistical power to detect variance components (Diez Roux, 2004). In a multilevel analysis of neighborhood effects, the power to detect variance components is influenced by the number of neighborhoods sampled and the number of residents per neighborhood. In examining this issue, Diez Roux (2004) and Snijders and Bosker (1999) suggest that even when variance estimates are very small, this does not mean that the data imply absolute certainty that the population value of the variance estimate is equal to zero, or that the effects of neighborhood variables on individual-level outcomes are not worth investigating.

The findings from the current study can help to inform the development of policy-relevant interventions directed at both individual- and the neighborhood-level contexts to delay the rate of physical function decline in aging populations. Specifically, this study identified those residing in more disadvantaged neighborhoods as having lower levels of physical function. This suggests that any targeted neighborhood-level intervention should focus on neighborhoods with greater levels of socioeconomic disadvantage. For example, smoking is associated with accelerated declines in physical function (Nelson et al., 1994), and previous work in Brisbane has shown that residents of more disadvantaged neighborhood are more likely to smoke (Turrell et al., 2012). Interventions such as decreasing the number of tobacco outlets, especially in disadvantaged neighborhoods, might contribute to a reduction of socioeconomic disparities in physical function. Establishing the mechanisms between neighborhood disadvantage and physical function is crucial to the design of community-based interventions, as these processes are more amenable to change and more sustainable compared to changing individual behavior that tend to be more challenging and short lived (Franco et al., 2014; Lorenc et al., 2013). This remains a priority for future research in this field.

5. Conclusion

Living in a disadvantaged neighborhood was associated with poorer physical function, even after adjustment for individual-level factors. Future studies should explore the mechanisms that explain why residents of advantaged and disadvantaged neighborhoods differ in their functional status.

Conflict of Interest statement

The authors have no conflict of interest to declare.

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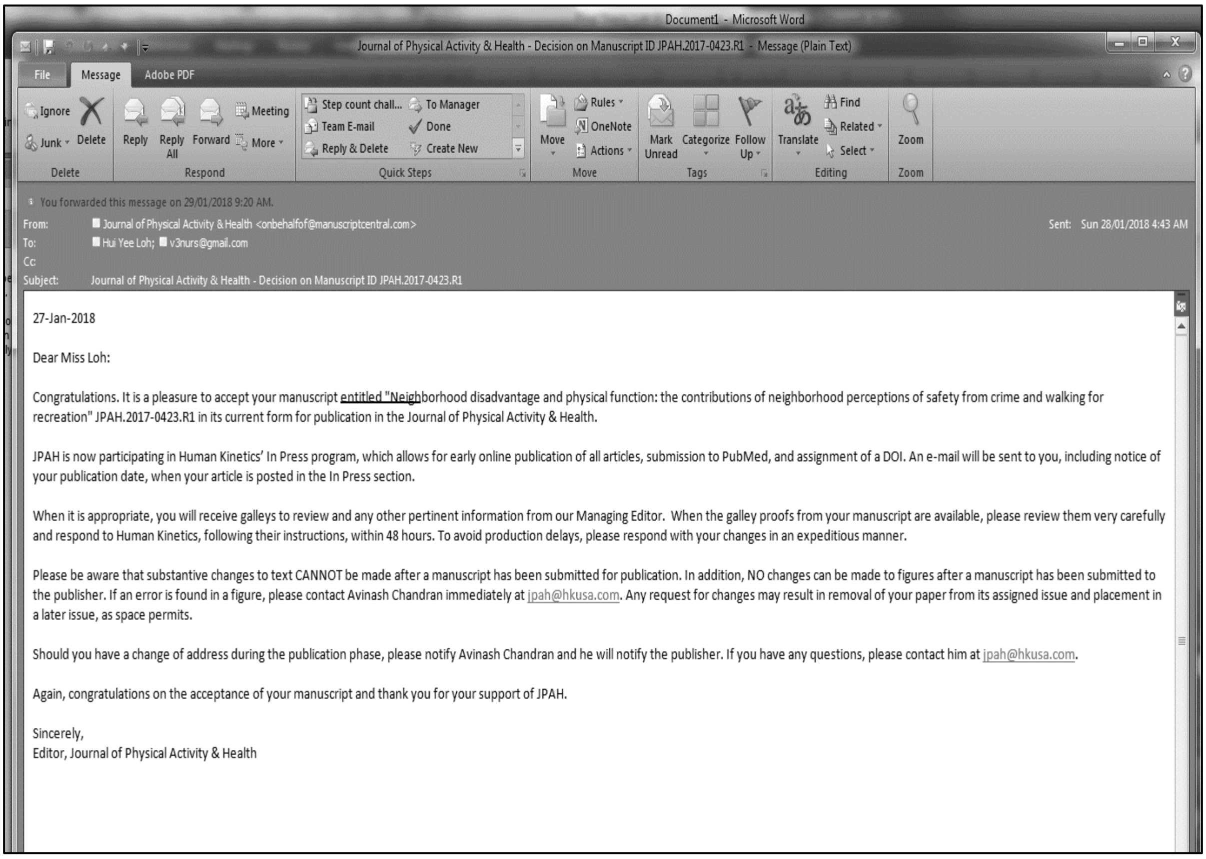
Publication for Study Two (Chapter 5)

In the case of Study Two, the nature and contribution to the work ‘Neighbourhood disadvantage and physical function: is the relationship explained by neighbourhood perceptions of safety from crime and walking for recreation?’ was the following:

	Name	Nature of contribution	Extent of contribution (%)	Signature
1	**Venurs HY Loh**	Critical literature review and development of research questions, data preparation, analysis design, statistical analysis, interpretation of results, tables, writing of manuscript, submission to journal, accepts overall responsibility for the publication	55	
2	**Jerome N Rachele**	Assisted with design of analysis and interpretation of results, commented on manuscript drafts	10	
3	**Wendy J Brown**	Designed and conducted the HABITAT study, assisted with design of analysis, interpretation of results and commented on manuscript drafts	10	Wendy Brown
4	**Fatima Ghani**	Commented on manuscript drafts	5	
5	**Gavin Turrell**	Designed and conducted the HABITAT study, facilitated development of research question, assisted with design of analysis and commented on manuscript drafts	20	

Status: Accepted for publication at Journal of Physical Activity and Health



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Journal of Physical Activity & Health - Decision on Manuscript ID JPAH.2017-0423.R1 - Message (Plain Text)

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Cc:

Subject: Journal of Physical Activity & Health - Decision on Manuscript ID JPAH.2017-0423.R1

27-Jan-2018

Dear Miss Loh:

Congratulations. It is a pleasure to accept your manuscript entitled "Neighborhood disadvantage and physical function: the contributions of neighborhood perceptions of safety from crime and walking for recreation" JPAH.2017-0423.R1 in its current form for publication in the Journal of Physical Activity & Health.

JPAH is now participating in Human Kinetics' In Press program, which allows for early online publication of all articles, submission to PubMed, and assignment of a DOI. An e-mail will be sent to you, including notice of your publication date, when your article is posted in the In Press section.

When it is appropriate, you will receive galleys to review and any other pertinent information from our Managing Editor. When the galley proofs from your manuscript are available, please review them very carefully and respond to Human Kinetics, following their instructions, within 48 hours. To avoid production delays, please respond with your changes in an expeditious manner.

Please be aware that substantive changes to text CANNOT be made after a manuscript has been submitted for publication. In addition, NO changes can be made to figures after a manuscript has been submitted to the publisher. If an error is found in a figure, please contact Avinash Chandran immediately at jpah@hkusa.com. Any request for changes may result in removal of your paper from its assigned issue and placement in a later issue, as space permits.

Should you have a change of address during the publication phase, please notify Avinash Chandran and he will notify the publisher. If you have any questions, please contact him at jpah@hkusa.com.

Again, congratulations on the acceptance of your manuscript and thank you for your support of JPAH.

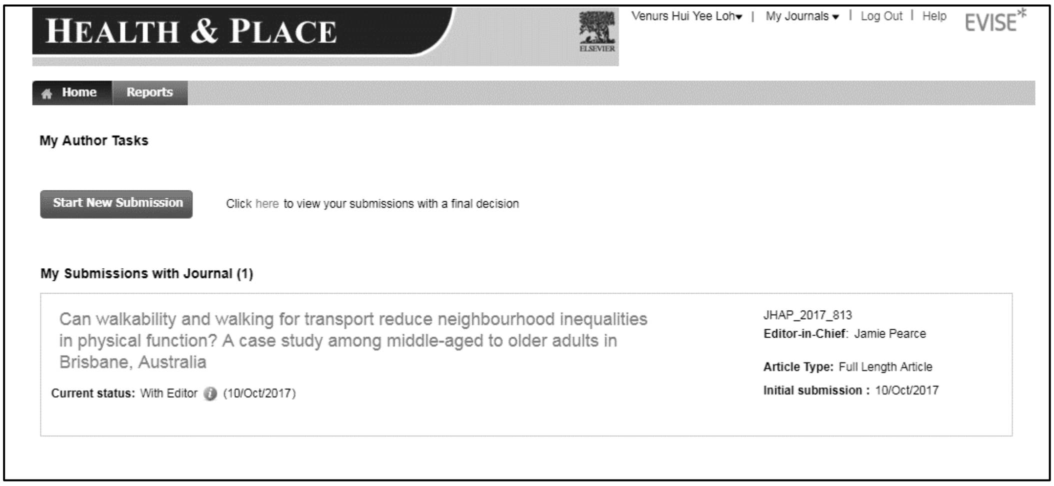
Sincerely,
Editor, Journal of Physical Activity & Health

Publication for Study Three (Chapter 6)

In the case of Study Three, the nature and contribution to the work ‘Can walkability and walking for transport reduce neighbourhood inequalities in physical function? A case study among middle-aged to older adults in Brisbane’ was the following:

	Name	**Nature of contribution**	**Extent of contribution (%)**	**Signature**
1	**Venurs HY Loh**	Critical literature review and development of research questions, data preparation, analysis design, statistical analysis, interpretation of results, tables, writing of manuscript, submission to journal, accepts overall responsibility for the publication.	50	
2	**Jerome N Rachele**	Assisted with design of analysis and interpretation of results, commented on manuscript drafts	10	
3	**Wendy J Brown**	Designed and conducted the HABITAT study, assisted with interpretation of results and commented on manuscript drafts	10	Wendy Brown
4	**Fatima Ghani**	Commented on manuscript drafts	5	
5	**Simon Washington**	Commented on manuscript drafts	5	
6	**Gavin Turrell**	Design and conduct of the HABITAT study, facilitated development of research question, assisted with design of analysis, interpretation of results and commented on manuscript drafts	20	

Status: With the editor of Health & Place



APPENDIX II: HABITAT SURVEY (2013)

A SURVEY ABOUT HEALTH, WELLBEING, LIFE AND RECREATION FOR PEOPLE AGED 45–75 YEARS

This project is funded by the National Health and Medical Research Council

HABITAT

how areas in brisbane influence health and activity

We greatly appreciate your help with this survey.
Your answers are very important to us.

Please remember:

- Your answers will be treated as strictly **PRIVATE AND CONFIDENTIAL.**
- There are no right or wrong answers: We just want to know what YOU think.
- The person doing the survey MUST be the person to whom it is addressed.
- Some of the questions may seem similar to each other. However, it will help us greatly if you answer all the questions.

If you have any questions:
Please call our Freecall number on 1800 452 543.

Once you have completed the survey, please return it in the enclosed reply paid envelope (no stamps necessary).

Some questions in this survey ask about your suburb. When we talk about 'your suburb', this means the [Suburb] area.

SECTION 1: You and your suburb

1.1 Overall, how would you rate your suburb as a place to live?

Please tick one box.	Excellent	Very Good	Good	Fair	Poor
	☐	☐	☐	☐	☐

1.2 The following statements are about your suburb and the people living around you. How much do you agree or disagree with each statement?

Please tick the box that best applies to you and your suburb.	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
I have a lot in common with many people in my suburb	☐	☐	☐	☐	☐
If I no longer lived here, hardly anyone around here would notice	☐	☐	☐	☐	☐
I am good friends with many people in my suburb	☐	☐	☐	☐	☐
I generally trust my neighbours to look out for my property	☐	☐	☐	☐	☐
I have little to do with most people in my suburb	☐	☐	☐	☐	☐
Most of the time, people in my suburb try to be helpful	☐	☐	☐	☐	☐
Generally speaking, people in my suburb can be trusted	☐	☐	☐	☐	☐
Most of the time, people in my suburb just look out for themselves	☐	☐	☐	☐	☐
I would like to move from my suburb	☐	☐	☐	☐	☐

1.3 Do you or someone else in your household own a dog(s)?

Please tick one box.	Yes	No	
	☐ ↓	☐ →	*PLEASE GO TO QUESTION 1.5 ON PAGE 2*

1.4 In a usual week, how much time in total, if any, do you personally walk or jog with your dog(s) in your suburb?

Hours	*Minutes*

If NONE, please write 0

1.5 About how long would it take you to **WALK** from your home to the **NEAREST** business or facility listed below? **(Please think of the closest one)**

Please tick one box for each item.	1–5 minutes	6–10 minutes	11–20 minutes	21–30 minutes	More than 30 minutes	Don't know
Supermarket	☐	☐	☐	☐	☐	☐
Bike path	☐	☐	☐	☐	☐	☐
Post office	☐	☐	☐	☐	☐	☐
Oval or sports field	☐	☐	☐	☐	☐	☐
Library	☐	☐	☐	☐	☐	☐
Bus stop	☐	☐	☐	☐	☐	☐
Train station	☐	☐	☐	☐	☐	☐
Café/restaurant	☐	☐	☐	☐	☐	☐
Public park	☐	☐	☐	☐	☐	☐
Fruit and vegetable shop	☐	☐	☐	☐	☐	☐
Ferry terminal	☐	☐	☐	☐	☐	☐
Post box	☐	☐	☐	☐	☐	☐

1.6 The following statements are about **crime and safety** in your suburb. How much do you agree or disagree with each statement?

Please tick the box that best applies to your suburb.	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
There is a lot of crime in my suburb	☐	☐	☐	☐	☐
Children are safe walking around the suburb during the day	☐	☐	☐	☐	☐
The level of crime in my suburb makes it unsafe to walk on the streets at night	☐	☐	☐	☐	☐
There are rowdy youth on the streets or hanging around in parks in my suburb	☐	☐	☐	☐	☐
The level of crime in my suburb makes it unsafe to walk on the streets during the day	☐	☐	☐	☐	☐
In my suburb, I would feel safe walking home from a bus stop or train station at night	☐	☐	☐	☐	☐

SECTION 2: Your activity and recreation

The next questions are about any physical activities that you may have done in the **LAST WEEK**:

2.1 a) In the LAST WEEK, how many times have you walked **continuously, for at least 10 minutes,** for recreation, exercise, or to get to or from places?

Write in number — *If NONE, please write 0*

b) What do you estimate was the total time you spent walking in this way in the LAST WEEK?

Hours *Minutes*

2.2 a) In the LAST WEEK, how many times did you do any vigorous gardening or heavy work around the yard, which made you breathe harder or puff and pant?

Write in number — *If NONE, please write 0*

b) What do you estimate was the total time that you spent doing vigorous gardening or heavy work around the yard in the LAST WEEK?

Hours *Minutes*

The next questions **EXCLUDE** household chores, gardening, or yard work:

2.3 a) In the LAST WEEK, how many times did you do any vigorous physical activity which made you breathe harder or puff and pant?

Examples: Jogging, cycling, aerobics, competitive tennis

Write in number — *If NONE, please write 0*

b) What do you estimate was the total time that you spent doing this vigorous physical activity in the LAST WEEK?

Hours *Minutes*

2.4 a) In the LAST WEEK, how many times did you do any other more moderate physical activities that you have not already mentioned?

Examples: Gentle swimming, social tennis, golf

Write in number — *If NONE, please write 0*

b) What do you estimate was the total time that you spent doing these activities in the LAST WEEK?

Hours *Minutes*

2.5 In the LAST WEEK on how many days did you do exercise to:

Please tick one box for each item.	None	1 day	2 days	3-5 days	6-7 days
Increase strength or tone (e.g. lifting weights, sit-ups, push-ups, elastic bands/therabands)	☐	☐	☐	☐	☐
Improve balance or flexibility (e.g. stretching, yoga, tai chi)	☐	☐	☐	☐	☐

2.6 The next two questions are about walking and cycling for RECREATION, LEISURE OR EXERCISE.
When answering these questions please DO NOT count walking or cycling for transport.

a) What do you estimate was the total time that you spent walking for recreation, leisure, or exercise in the LAST WEEK?

Hours ☐☐ *Minutes* ☐☐

If NONE, please write 0

b) What do you estimate was the total time that you spent cycling for recreation, leisure, or exercise in the LAST WEEK?

Hours ☐☐ *Minutes* ☐☐

If NONE, please write 0

2.7 How often over the LAST MONTH did the following people do physical activity, including walking, WITH YOU?

Please tick one box for each item.	Never	Once or twice	3–4 times	5–9 times	10 times or more	Not applicable	Don't know
Your spouse or partner	☐	☐	☐	☐	☐	☐	☐
Close family members	☐	☐	☐	☐	☐	☐	☐
People at work	☐	☐	☐	☐	☐	☐	☐
Close friends	☐	☐	☐	☐	☐	☐	☐
Your neighbours or other people in your neighbourhood	☐	☐	☐	☐	☐	☐	☐

2.8 This question asks about how much time you spend **SITTING** in the following situations **ON A USUAL DAY**:

	On a WEEK DAY			On a WEEKEND DAY	
a) While travelling to and from places	Hours	Minutes	→	Hours	Minutes
	If NONE, please write 0			If NONE, please write 0	
b) While watching television (including DVDs, videos, Xbox and Playstation)	Hours	Minutes	→	Hours	Minutes
	If NONE, please write 0			If NONE, please write 0	
c) While using the computer at home	Hours	Minutes	→	Hours	Minutes
	If NONE, please write 0			If NONE, please write 0	
d) In your leisure time, NOT including TV and the computer (e.g. hobbies, reading, dining out)	Hours	Minutes	→	Hours	Minutes
	If NONE, please write 0			If NONE, please write 0	

SECTION 3: Your thoughts and feelings about activities

3.1 How strong or weak is your intention to be physically active?

Please tick one box.	Very weak	Weak	Unsure	Strong	Very strong
	☐	☐	☐	☐	☐

3.2 Here are some things that might make it difficult to do physical activity. Which of these things make it difficult for YOU to do physical activity?

Please tick one box for each item.	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
Lack of money	☐	☐	☐	☐	☐
Poor health	☐	☐	☐	☐	☐
Facilities are too far away	☐	☐	☐	☐	☐
Problems with transport	☐	☐	☐	☐	☐
My age	☐	☐	☐	☐	☐
Cost of membership/equipment	☐	☐	☐	☐	☐
I do not enjoy physical activity	☐	☐	☐	☐	☐
Lack of time	☐	☐	☐	☐	☐
I have a disability	☐	☐	☐	☐	☐
I'm too shy or embarrassed	☐	☐	☐	☐	☐
My weight	☐	☐	☐	☐	☐
Lack of access to childcare	☐	☐	☐	☐	☐
Lack of skill	☐	☐	☐	☐	☐
Work demands	☐	☐	☐	☐	☐
I have an injury	☐	☐	☐	☐	☐

3.3 Do you think that you could do physical activity regularly when:

Please tick one box for each item.	I know I could not		Maybe I could		I know I could
You have chores to do	☐	☐	☐	☐	☐
You are feeling sad or depressed	☐	☐	☐	☐	☐
You have had a long, tiring day	☐	☐	☐	☐	☐
Your family wants more time with you	☐	☐	☐	☐	☐
You have work demands	☐	☐	☐	☐	☐
You have social commitments	☐	☐	☐	☐	☐

SECTION 4: # Your transport

In this section we would like to know about the types of transport you use, and your opinions about public and private transport.

4.1 On most weekdays (Monday to Friday), which type of transport do you **MAINLY** use to get to and from places?

Please tick the main one.	Public transport	Car or motorcycle	Walk	Bicycle	Other *(please specify)*
	☐	☐	☐	☐	

4.2 Do you have a motor vehicle available for your personal use?

Please tick one box.	Yes, always	Yes, sometimes	No	Do not drive
	☐	☐	☐	☐

4.3 **YESTERDAY**, how much time did you spend travelling by:

	Hours	Minutes	
Private Motor Vehicle (car, motorbike or taxi)			*If NONE, please write 0*
Public Transport (bus, train, or ferry)			*If NONE, please write 0*
Walking			*If NONE, please write 0*
Cycling			*If NONE, please write 0*

4.4 **YESTERDAY**, what day of the week was it?

Please tick one box.	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	☐	☐	☐	☐	☐	☐	☐

4.5 How strongly do you agree or disagree with the following statements?

Please tick one box for each item.	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
Public transport can sometimes be easier than driving	☐	☐	☐	☐	☐
Travelling by car is safer overall than walking	☐	☐	☐	☐	☐
Travelling by public transport is not very pleasant	☐	☐	☐	☐	☐
People need to walk and cycle more to reduce global warming	☐	☐	☐	☐	☐
Public transport is inconvenient and unreliable	☐	☐	☐	☐	☐
Travelling by car is safer overall than taking public transport	☐	☐	☐	☐	☐
People need to walk and cycle more to reduce traffic congestion	☐	☐	☐	☐	☐
Travelling by car is safer overall than riding a bike	☐	☐	☐	☐	☐
People need to walk and cycle more to improve the environment	☐	☐	☐	☐	☐
Using public transport takes too much time	☐	☐	☐	☐	☐
Traffic congestion is a problem in Brisbane	☐	☐	☐	☐	☐
I need a car to do many of the things that I do	☐	☐	☐	☐	☐
People need to use public transport more often to reduce traffic congestion	☐	☐	☐	☐	☐
I could manage pretty well without a car	☐	☐	☐	☐	☐
Public transport is expensive	☐	☐	☐	☐	☐

4.6 The next two questions are about walking and cycling for TRANSPORT. Transport includes things like travel to and from work, to do errands, or to go from place to place.

When answering these questions please DO NOT count walking or cycling for exercise or recreation.

a) What do you estimate was the total time that you spent walking for transport in the LAST WEEK?

Hours ☐☐ *Minutes* ☐☐

If NONE, please write 0

b) What do you estimate was the total time that you spent cycling for transport in the LAST WEEK?

Hours ☐☐ *Minutes* ☐☐

If NONE, please write 0

SECTION 5: Your health, wellbeing and lifestyle

5.1 All things considered how satisfied are you with your life as a whole?

Please tick one box.

Dissatisfied ← → Satisfied

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

5.2 In general, would you say your health is?

Please tick one box.

Excellent	Very good	Good	Fair	Poor
☐	☐	☐	☐	☐

5.3 In the **LAST YEAR** how often has your health restricted you from doing physical activity?

Please tick one box.

None of the time	A little of the time	Some of the time	Most of the time	All of the time
☐	☐	☐	☐	☐

5.4 Do you regularly need help with daily tasks because of long-term illness or disability (e.g. help with personal care, getting around, preparing meals, etc.)?

Please tick one box.

Yes	No
☐	☐

5.5 How tall are you without shoes?
(Please tell us in either centimetres or feet and inches.)

Please check using your driver's licence if you have one.

Centimetres		Feet	Inches
	OR		

5.6 How much do you weigh without your clothes and shoes?
(Please tell us in either kilograms or stone and pounds.)

Please check using a set of scales if you have them.

Kilograms		Stone	Pounds
	OR		

5.7 On a usual **24 hour day**, how many **HOURS** do you spend sleeping (including at night, naps or any other time during the day)?

On a WEEK DAY	On a WEEKEND DAY
Hours ☐☐	AND → Hours ☐☐

5.8 During the **LAST WEEK**, how would you rate your sleep quality overall?

Please tick one box.	Excellent	Very good	Good	Fair	Poor
	☐	☐	☐	☐	☐

5.9 In the **LAST YEAR**, has a doctor, nurse, or health professional talked to you about physical activity or advised you to do exercise?

Please tick one box.	Yes	No
	☐	☐

5.10 To what extent do you agree or disagree with following statements?

Please tick one box for each item.	Strongly disagree	Disagree	Agree	Strongly agree
I am currently trying to lose weight	☐	☐	☐	☐
Doing physical activity is an important part of my weight management	☐	☐	☐	☐

5.11 Which **ONE** of the following best describes your cigarette smoking?

Please tick one.

☐	I smoke daily →	How many cigarettes do you usually smoke each day? →	What year did you start smoking?
☐	I smoke occasionally →		What year did you start smoking?
☐	I don't smoke now, but I used to →	What year did you quit smoking? →	What year did you start smoking?
☐	I have never smoked		

5.12 Have you ever been told by a doctor or nurse that you have any of the **LONG-TERM** health conditions listed below?
Please only include those conditions that have lasted, or are likely to last, for **SIX (6) MONTHS OR MORE**.

Please tick one box for each condition.	Yes	No
Arthritis	☐	☐
Asthma	☐	☐
Any type of cancer	☐	☐
Chronic bronchitis or emphysema	☐	☐
Diabetes	☐	☐
Heart/coronary disease	☐	☐
High blood pressure/hypertension	☐	☐
Any other serious circulatory condition (e.g. stroke, hardening of the arteries)	☐	☐
Osteoporosis	☐	☐
Anxiety	☐	☐
High cholesterol	☐	☐
Injury	☐	☐
Depression	☐	☐
Other *(please describe)*		

5.13 To what extent do you agree or disagree with the following statements?

Please tick one box for each item.	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
There is really no way I can solve some of the problems I have	☐	☐	☐	☐	☐
Sometimes I feel that I'm being pushed around in life	☐	☐	☐	☐	☐
I have little control over the things that happen to me	☐	☐	☐	☐	☐
I can do just about anything I really set my mind to	☐	☐	☐	☐	☐
I often feel helpless in dealing with the problems of life	☐	☐	☐	☐	☐
What happens to me in the future mostly depends on me	☐	☐	☐	☐	☐
There is little I can do to change many of the important things in my life	☐	☐	☐	☐	☐

5.14 Below are some statements about feelings and thoughts. Please tick the box that **BEST** describes your experience of each over the **LAST TWO (2) WEEKS**.

Please tick one box for each item.	None of the time	Rarely	Some of the time	Often	All of the time
I've been feeling optimistic about the future	☐	☐	☐	☐	☐
I've been feeling useful	☐	☐	☐	☐	☐
I've been feeling relaxed	☐	☐	☐	☐	☐
I've been dealing with problems well	☐	☐	☐	☐	☐
I've been thinking clearly	☐	☐	☐	☐	☐
I've been feeling close to other people	☐	☐	☐	☐	☐
I've been able to make up my own mind about things	☐	☐	☐	☐	☐

5.15 During the **LAST FOUR (4) WEEKS** how often did you feel:

Please tick one box for each item.	None of the time	A little of the time	Some of the time	Most of the time	All of the time
Nervous	☐	☐	☐	☐	☐
Hopeless	☐	☐	☐	☐	☐
Restless or fidgety	☐	☐	☐	☐	☐
So sad that nothing could cheer you up	☐	☐	☐	☐	☐
That everything was an effort	☐	☐	☐	☐	☐
Worthless	☐	☐	☐	☐	☐

5.16 How much of the time in the **LAST FOUR (4) WEEKS** did you:

Please tick one box for each item.	None of the time	A little of the time	Some of the time	Most of the time	All of the time
Feel full of life	☐	☐	☐	☐	☐
Have lots of energy	☐	☐	☐	☐	☐
Feel worn out	☐	☐	☐	☐	☐
Feel tired	☐	☐	☐	☐	☐

We all fall from time to time. A fall is when you suddenly find yourself on the ground, without intending to get there, after you were either in a lying, sitting or standing position.

5.17 How many times have you fallen during the PAST ONE (1) YEAR?

Please tick one box.

None	Once	2 times	3-4 times	5 or more times	Don't know
☐	☐	☐	☐	☐	☐

5.18 Were you hospitalised as a result of a fall during the PAST ONE (1) YEAR?

Please tick one box.

Yes	No
☐	☐

5.19 Have you had a fracture or broken bone within the PAST TWO (2) YEARS?

Please tick one box.

Yes	No
☐	☐ → *PLEASE GO TO QUESTION 5.21 ON PAGE 14*

5.20 Which bone(s) were fractured or broken within the PAST TWO (2) YEARS?

Please tick ALL that apply.

Hip	Pelvis	Wrist	Leg	Arm	Shoulder	Back
☐	☐	☐	☐	☐	☐	☐

5.21 The following is a list of activities that you might do during a typical day.
Does your health now limit you in these activities? If so, how much?

Please tick one box for each item.	Yes, limited a lot	Yes, limited a little	No, not limited at all
Vigorous activities such as running, lifting heavy objects, participating in strenuous sports	☐	☐	☐
Moderate activities such as moving a table, pushing a vacuum cleaner, bowling or playing golf	☐	☐	☐
Lifting or carrying groceries	☐	☐	☐
Climbing several flights of stairs	☐	☐	☐
Climbing one flight of stairs	☐	☐	☐
Bending, kneeling or stooping	☐	☐	☐
Walking more than one kilometre	☐	☐	☐
Walking half a kilometre	☐	☐	☐
Walking 100 metres	☐	☐	☐
Bathing or dressing yourself	☐	☐	☐

5.22 In the **LAST TWELVE (12) MONTHS**, to what extent have you experienced any of the following as a result of your physical abilities (i.e. strength, mobility, flexibility)?					
Please tick one box for each item.	All of the time	Most of the time	Some of the time	A little of the time	None of the time
Cut down the amount of time you spent doing everyday activities	☐	☐	☐	☐	☐
Cut down the number of everyday activities you did	☐	☐	☐	☐	☐
Accomplished less than you would like	☐	☐	☐	☐	☐
Had difficulty doing everyday activities (e.g. it took extra time)	☐	☐	☐	☐	☐

5.23 In the **LAST TWELVE (12) MONTHS**, how often did you experience each of the following:				
Please tick one box for each item.	Never	Rarely	Sometimes	Often
Stiff or painful joints	☐	☐	☐	☐
Severe tiredness	☐	☐	☐	☐
Back pain	☐	☐	☐	☐
Breathing difficulties	☐	☐	☐	☐
Chest pain	☐	☐	☐	☐
Palpitations	☐	☐	☐	☐
Eyesight problems	☐	☐	☐	☐
Headaches	☐	☐	☐	☐
Leaking urine (incontinence)	☐	☐	☐	☐
Bowel problems	☐	☐	☐	☐

5.24 How often do you feel the way described in the following statements?			
Please tick one box for each item.	Hardly ever	Some of the time	Often
I feel left out	☐	☐	☐
I feel isolated from others	☐	☐	☐
I lack companionship	☐	☐	☐

5.25 Have you experienced any of the following events in the **LAST TWO (2) YEARS**?

Please tick one box for each item.	Yes	No
Increased responsibilities at work	☐	☐
Reduced hours at work	☐	☐
Retired from work	☐	☐
My partner retired	☐	☐
One or more of my children left home	☐	☐
Increased hours at work	☐	☐
Birth of a grandchild	☐	☐
Increased care responsibilities for a child	☐	☐
Increased care responsibilities for a grandchild	☐	☐
Increased care responsibilities for an adult	☐	☐
Serious stress or conflict at home or in the family	☐	☐
I became unemployed	☐	☐
Serious stress or conflict at work	☐	☐
Separation or divorce from my partner	☐	☐
Serious personal illness or injury	☐	☐
Serious illness or injury to a close friend or relative	☐	☐
Death of a close friend or relative	☐	☐
Death of my partner	☐	☐
Increased financial difficulties	☐	☐

5.26 This question is about the **JANUARY 2011 FLOODS** in Brisbane. To what extent are you experiencing personal difficulties as a result of these floods?
(e.g. easily upset, sadness, anger, poor concentration, fatigue, sleep difficulties, feeling disorganised, difficulties with decisions, less interested in things)

Please tick one box.	Not at all		A moderate extent		A great extent
	☐	☐	☐	☐	☐

SECTION 6: # You and your household

This last section asks a few questions about you and your household.

6.1 What is your date of birth (e.g. 23/05/1951)

Day	Month	Year

6.2 Are you:

Please tick one box.

Male	Female
☐	☐

6.3 Which ONE of the following best describes your current living arrangement?

Please tick one box.

Living alone with no children	☐
Single parent living with one or more children	☐
Single and living with friends or relatives	☐
Couple (married or de facto) living with no children	☐
Couple (married or de facto) living with one or more children	☐
Other *(please specify)*	

6.4 How many people in total live in your household?

Please include yourself, partner, children, and/or anyone else living with you.

6.5 How many children do you currently have living in your care (either full-time or part-time)?

Please provide the number for each age group.	None	Number aged 0 to 12 months	Number aged 1–5 years	Number aged 6–12 years	Number aged 13–17 years	Number aged 18 years or more
	☐					

6.6 Which ONE of the following best describes your current home ownership situation?

Please tick one box.	Own, **without** a mortgage	Own, **with** a mortgage	Private rental	Public housing	Other (e.g., border, company house	Don't know
	☐	☐	☐	☐	☐	☐

6.7 Do you regularly provide unpaid care or assistance (e.g. personal care, transport) to any other person because of their long-term illness, disability or frailty?

Please tick one box.

	Yes	No
	☐	☐

6.8 Which ONE of the following best describes your current employment situation?

Please tick ONE only.

Full-time paid work in a job, business or profession	☐	*PLEASE GO TO QUESTION 6.9 BELOW*
Part-time paid work in a job, business or profession	☐	
Casual paid work in a job, business or profession	☐	
Work without pay in a family or other business	☐	
Home duties not looking for work	☐	*PLEASE GO TO QUESTION 6.15 ON PAGE 20*
Unemployed looking for work	☐	
Retired	☐	
Permanently unable to work	☐	
Student	☐	
Other *(please specify)* ________	☐	

6.9 What is your current occupation? (If you have more than one job, we are interested in your MAIN job.)

*Please give full title (for example: Childcare Aide, Maths Teacher, Pastycook, Commercial Airline Pilot, Apprentice Toolmaker, etc). For **Public Servants**, state official designation and occupation. For **armed services personnel**, state rank and occupation.*

Full title of occupation: ________

6.10 In a usual week, how many hours per week do you work in your MAIN job?

Number of hours

☐

6.11 About how much time do you spend SITTING while at work ON A USUAL DAY:

Hours ☐☐ *Minutes* ☐☐

If NONE, please write 0

6.12 This question asks about physical activity in your MAIN job. On a usual working day, how often do you do each of the following while you are at work?

Please tick one box for each item.	None of the time	A little of the time	Some of the time	Most of the time	All of the time
Standing	☐	☐	☐	☐	☐
Walking	☐	☐	☐	☐	☐
Heavy labour or physically demanding work	☐	☐	☐	☐	☐

6.13 What type of transport do you MAINLY use to travel to work? If you use more than one type of transport (e.g. drive the car to the train station) please tick each option.

Please tick ALL that apply.	Bus	Train	Ferry	Car	Walk	Motorcycle	Bicycle	Taxi	Other
	☐	☐	☐	☐	☐	☐	☐	☐	☐

6.14 How long does it usually take you to get to work?

Please tick one box.	Less than 15 minutes	15–30 minutes	31–60 minutes	More than 60 minutes
	☐	☐	☐	☐

We would be grateful if you could provide us with an estimate of your total household income.

People may feel uncomfortable providing information about their income. To make this easier we have grouped the incomes into categories so that your actual income can't be identified.

By answering this question you will help us to achieve our aim of ensuring that all Brisbane residents, regardless of income, have equal access to the facilities and services they need. Please be reassured that your answer will be treated as strictly private and confidential.

6.15 Please add up the amount of **BEFORE TAX** income received by **ALL** members of your household, and tick the box that comes closest to this number. Please indicate income either per year, per fortnight, or per week.

Tick one box only.

Per year	OR	Per fortnight	OR	Per week
☐ Less than $15,599		☐ less than $600		☐ Less than $300
☐ $15,600–20,799		☐ $600–799		☐ $300–399
☐ $20,800–25,999		☐ $800–999		☐ $400–499
☐ $26,000–31,199		☐ $1,000–1,199		☐ $500–599
☐ $31,200–36,399		☐ $1,200–1,399		☐ $600–699
☐ $36,400–41,599		☐ $1,400–1,599		☐ $700–799
☐ $41,600–51,999		☐ $1,600–1,999		☐ $800–999
☐ $52,000–72,799		☐ $2,000–2,799		☐ $1,000–1,399
☐ $72,800–93,599		☐ $2,800–3,599		☐ $1,400–1,799
☐ $93,600–129,999		☐ $3,600–4,999		☐ $1,800–2,499
☐ $130,000 or more		☐ $5,000 or more		☐ $2,500 or more
☐ Don't know				
☐ Don't want to answer this				

6.16 How well do you manage on the income you have available?

Please tick one box.	It is impossible	It is difficult all the time	It is difficult some of time	It is not too bad	It is easy
	☐	☐	☐	☐	☐

FINALLY...

We are planning a follow-up of the HABITAT study in the near future. We are interested in looking at how changes in your area over time affect your lifestyle, health and well-being. It would greatly assist us if we were able to contact you again. Please provide as many details as possible below.

Your current details			
First name		Last name	
Street address			
Suburb		Postcode	
Home telephone			
Email address			
Mobile phone			

In case you change address, please provide the contact details of someone **not** living with you who will know where you are if you move (e.g. parent, son/daughter, brother/sister, or close friend). Can you please let this person know that you have given this study their details in case you move and they need to be contacted?			
First name		Last name	
Street address			
Suburb		Postcode	
Home telephone			
Email address			
Mobile phone			

THANK YOU

Thank you for the time and effort you have put into completing this survey for us. It is very much appreciated and the information you have provided is important for our research.

Please return this survey in the enclosed reply paid envelope (no stamps necessary).


family
play
work
enjoy
relax
place
live
ONLY
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Appendix III: Research Ethics Approval Certificate

QUT

University Human Research Ethics Committee

HUMAN ETHICS APPROVAL CERTIFICATE

NHMRC Registered Committee Number EC00171

Date of Issue: 13/2/14 (supersedes all previously issued certificates)

Dear Prof Gavin Turrell

A UHREC should clearly communicate its decisions about a research proposal to the researcher and the final decision to approve or reject a proposal should be communicated to the researcher in writing. This Approval Certificate serves as your written notice that the proposal has met the requirements of the *National Statement on Research involving Human Participation* and has been approved on that basis. You are therefore authorised to commence activities as outlined in your proposal application, subject to any specific and standard conditions detailed in this document.

Within this Approval Certificate are:

* Project Details
* Participant Details
* Conditions of Approval (Specific and Standard)

Researchers should report to the UHREC, via the Research Ethics Coordinator, events that might affect continued ethical acceptability of the project, including, but not limited to:

(a) serious or unexpected adverse effects on participants; and
(b) proposed significant changes in the conduct, the participant profile or the risks of the proposed research.

Further information regarding your ongoing obligations regarding human based research can be found via the Research Ethics website http://www.research.qut.edu.au/ethics/ or by contacting the Research Ethics Coordinator on 07 3138 2091 or ethicscontact@qut.edu.au

If any details within this Approval Certificate are incorrect please advise the Research Ethics Unit within 10 days of receipt of this certificate.

Project Details

Category of Approval:	Human Negligible-Low Risk		
Approved From:	12/04/2013	**Approved Until:**	12/04/2017 (subject to annual reports)
Approval Number:	1300000161		
Project Title:	A longitudinal multilevel study of physical activity, sedentary behaviour, and physical function in mid-to-late adulthood		
Experiment Summary:	Better understand the trajectory of decline in physical function and the factors that influence this trajectory.		

Investigator Details

Chief Investigator: Prof Gavin Turrell

Other Staff/Students:

Investigator Name	**Type**	**Role**
Mrs Lee-Ann Wilson	Internal	Associate Investigator
Dr Andrea Nathan	Internal	Project Manager
Ms Sophie Miller	Internal	Research Assistant

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University Human Research Ethics Committee

HUMAN ETHICS APPROVAL CERTIFICATE

NHMRC Registered Committee Number EC00171

Date of Issue: 13/2/14 (supersedes all previously issued certificates)

Conditions of Approval

Specific Conditions of Approval:
None apply

Standard Conditions of Approval:
The University's standard conditions of approval require the research team to:

1. Conduct the project in accordance with University policy, NHMRC / AVCC guidelines and regulations, and the provisions of any relevant State / Territory or Commonwealth regulations or legislation;

2. Respond to the requests and instructions of the University Human Research Ethics Committee (UHREC);

3. Advise the Research Ethics Coordinator immediately if any complaints are made, or expressions of concern are raised, in relation to the project;

4. Suspend or modify the project if the risks to participants are found to be disproportionate to the benefits, and immediately advise the Research Ethics Coordinator of this action;

5. Stop any involvement of any participant if continuation of the research may be harmful to that person, and immediately advise the Research Ethics Coordinator of this action;

6. Advise the Research Ethics Coordinator of any unforeseen development or events that might affect the continued ethical acceptability of the project;

7. Report on the progress of the approved project at least annually, or at intervals determined by the Committee;

8. (Where the research is publicly or privately funded) publish the results of the project is such a way to permit scrutiny and contribute to public knowledge; and

9. Ensure that the results of the research are made available to the participants.

Modifying your Ethical Clearance:
Requests for variations must be made via submission of a Request for Variation to Existing Clearance Form (http://www.research.qut.edu.au/ethics/forms/hum/var/var.jsp) to the Research Ethics Coordinator. Minor changes will be assessed on a case by case basis.

It generally takes 7-14 days to process and notify the Chief Investigator of the outcome of a request for a variation.

Major changes, depending upon the nature of your request, may require submission of a new application.

Audits:
All active ethical clearances are subject to random audit by the UHREC, which will include the review of the signed consent forms for participants, whether any modifications / variations to the project have been approved, and the data storage arrangements.

End of Document

AFTERWORD: WHAT WOULD HAVE HAPPENED TO ME HAD I NOT MOVED TO AUSTRALIA 10 YEARS AGO?

I was born in Malaysia, a country classified as ‘developing’, and raised in a middle-income family that prioritises education above all else. Therefore, moving to Australia for my bachelor’s degree seemed like a rite of passage for me. In my Introduction chapter, I began by describing the social inequalities in health, and how health is unequally distributed across the world. I gave an example of life expectancy between the world’s healthiest (Japan) and the unhealthiest (Sierra Leone) countries. If you are born in Japan, your life expectancy will be 84 years, but if you are born in Sierra Leone, your life expectancy will be 50 years. The gap between these two countries is 34 years. I couldn’t help but look up the life expectancy gap between Malaysia and Australia. According to World Health Organization, the life expectancy gap between Australia and Malaysia is 13 years. Could it be true that I would ultimately gain 13 years of life if I continue to live here? Who knows? Nevertheless, my experience in Australia has been a positive one. I do indeed lived my life quite differently as compared with how I used to live back home in Malaysia.

Reflecting upon my thesis and my life, I am intrigued that some of the findings from this thesis are closely linked to my own life. The environments in which I live, grow, study and work have certainly played vital roles in shaping my behaviour and health in the following ways:

1. **Fairer scholarship system**

   According to the Malaysian policy, ethnic Malays are prioritised for attaining business licences, government jobs, cheaper housing and access to higher education (entrance and scholarship). The Malaysian education policy does not practice meritocracy. As a Malaysian Chinese, regardless of my academic performance, my chance of getting a place in any government university in Malaysia is 19%,[1] and to attain a scholarship, that chance is even lower. In December 2013, I was offered a scholarship in Australia to start a PhD—something I never thought possible had happened to me in a foreign country. I am eternally grateful for that, and I believe this has changed my future for the better.

2. More supportive built environment for leisure-time physical activities

During Obama's first visit to Brisbane in 2014, he described the weather in Brisbane as 'lovely today, perfect tomorrow'. I enjoy the weather in Brisbane, and further, Brisbane has well-maintained, safe and aesthetically pleasing environments and facilities (pedestrian paths, cycling paths, bridges) that allow individuals to go for a walk, run or cycle along the river. Running by the river every Sunday has since become my routine. However, in Malaysia, the humid and polluted air quality, fear of getting robbed, lack of designated sidewalks and aesthetically unpleasing environment makes it difficult for individuals to leave the house to exercise.

3. Better public transport system for transport-related physical activities

Fun fact about my family: the number of cars in my household is equivalent to the number of people in my household (n = 5). This may be shocking to some but it is relatively common in my country. The public transport system in Malaysia can sometimes be unreliable, and often overcrowded. More importantly, my experiences

[1] Pak, J "Is Malaysia university entry a level playing field?" *British Broadcast Cooperation News* 2 Sept. 2013.

> of using the public transport in Malaysia have been mostly unpleasant. Imagine waiting for the bus in the hot and humid weather, not knowing when the bus will arrive because no one follows the timetable (except for the train and metro). When the bus finally arrives, you enter into a space filled with people squashed against each other; everyone is perspiring because the air-conditioning system is broken down. You may have to endure this situation for a long time because the traffic conditions in Kuala Lumpur are dreadful. If I were given a choice, I would rather be stuck in the traffic in the comfort of my own car, than to be on an overcrowded bus. Even though the public transport system in Australia is not the greatest compared with other countries, such as like Singapore or Japan, it is still far better than the public transport experience I had in Malaysia. I enjoy taking public transport in Brisbane because the buses and trains are (most of the time) clean, and most importantly, I know they are coming (the timetable is displayed on most stops). Taking public transport here is much easier than driving.

I am by no means saying that Malaysia is a bad country. Not being in my country also means that I cannot be there for my family's milestones celebrations and weekly family dinners and, and worse, cannot immediately be there for my family when one of them is unwell. Malaysia is still the country that I love most, and things might have improved since 10 years ago. My point is, in terms of my health and wellbeing, Australia has made it easier for me to undertake healthier activities, and its fairer system in Australia has enabled me to pursue a higher education degree. These, I believe, will have significant implications for my physical and mental health.

So, what would have happened to me had I not moved to Australia? My best bet would be that I would not have pursued my master’s degree or PhD; running outdoors would not have crossed my mind; and I would continue to drive from place to place.
Could it be true that I would ultimately gain 13 years of life if I continue to live in Australia? Well, I still don’t know.

Has the environment in Brisbane, Australia contributed to my health so far? Absolutely!

End of Document