

# Associations among greenspace exposure, time in neighbourhood, physical activity, and childhood development

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**Jonathan Ward**

Student no: 9701560

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## **Abstract**

### *Background*

Regular moderate to vigorous physical activity (MVPA) has been identified as an important factor in healthy childhood development. However, evidence suggests that children in New Zealand and worldwide are generally not meeting recommended targets for daily MVPA. In order to understand and potentially influence children's engagement in physical activity, a substantial body of research has investigated many of the factors that are associated with children's MVPA. These variables include exposure to greenspaces and the neighbourhood environment. Both greenspace exposure and physical activity have also been associated with broader measures of children's development including cognition, emotional wellbeing, and risk-taking behaviour. The current research aimed to investigate the associations between greenspace exposure and time spent in the neighbourhood environment with the physical activity of children. The associations between these variables and measures of children's cognitive development, emotional wellbeing, and risk-taking behaviour were also explored.

### *Methods*

This observational study involved 118 participants aged 11-14 years from three intermediate schools in Auckland, New Zealand. Physical activity and geolocational data were recorded using accelerometers and portable global positioning system (GPS) receivers, respectively, over a 7-day monitoring period. Body mass index (BMI) and waist-to-height ratio (WHtR) were calculated from height, weight, and waist circumference. Participants also completed online cognitive testing, a computerised risk-appraisal tool, and a questionnaire for assessing emotional wellbeing and

sensation-seeking characteristics. Geolocational and physical activity data were merged, processed, and analysed to identify activity that occurred within greenspaces, and activity that occurred within the participants' neighbourhoods (defined by an 800 metre radius around their home address). Participants were grouped into quartiles based on their time spent in their neighbourhood for analysis. Generalised linear mixed models were used to quantify the associations between MVPA, greenspace exposure, and secondary outcome variables. Also, the associations between time in the neighbourhood, physical activity, and several other individual-level (BMI, Life satisfaction score), and neighbourhood-level (number and area of greenspaces, neighbourhood walkability score), variables were analysed in generalised linear models.

### *Results*

This study confirmed that greenspace exposure is positively associated with MVPA in children ( $\beta = 0.94$ ;  $p < 0.05$ ). Furthermore, both greenspace exposure and MVPA were related to greater emotional wellbeing, with the former exhibiting a stronger relationship than the latter. Risk-taking and sensation seeking scores were positively associated with MVPA, but not with greenspace exposure. No associations were detected between BMI, WHtR, cognitive domains, and either MVPA or greenspace exposure. Lower time in the neighbourhood was associated with lower engagement in MVPA; however, this relationship was not consistent amongst all quartiles. There were no other significant associations between time in neighbourhood and any other variables.

## *Conclusion*

The findings of this Thesis support the theory that for children, greenspaces are an important environmental influence on physical activity and emotional wellbeing. It provides evidence that children's greenspace exposure is associated with both increased MVPA, and higher levels of emotional wellbeing. It also provides some evidence that the amount of time spent in the neighbourhood environment is positively associated with children's physical activity levels, but not related to BMI, life satisfaction, or greenspace exposure. The analysis of neighbourhood-level variables found no relationships between time in the neighbourhood and the area or number of local greenspaces or the neighbourhood walkability score. This research adds to our knowledge of the importance of greenspaces in enhancing healthy childhood development.

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### **Attestation of Authorship**

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

Signed.....

Date.....

Name.....

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## **Chapter 1: Literature review**

### **1.1 Introduction**

Physical activity is widely acknowledged as a key factor in promoting health, with physical inactivity identified as the fourth leading risk factor for mortality globally (World Health Organisation, n.d.). Regular MVPA has been associated with numerous benefits in children, particularly cardiovascular health (through improved cholesterol and blood lipid profiles and decreased blood pressure); reduced markers of metabolic syndrome; improved musculoskeletal health (through increased muscular strength and bone mineral density); reduced risk of type 2 diabetes; reduced symptoms of depression and anxiety; and maintenance of a healthy weight (Janssen & LeBlanc, 2010). These benefits follow a dose-response relationship whereby the more physical activity accumulated, the greater the health benefit (Janssen & LeBlanc, 2010).

Because of these health promoting effects, reviews of the literature have concluded that children should engage in at least 60 minutes of MVPA per day (Janssen & Leblanc, 2010). In New Zealand, this recommended target has been adopted by the Ministry of Health (Ministry of Health, n.d.), however, the extent to which children meet this target is unclear. Surveys of physical activity levels in New Zealand youth have yielded contradictory results due partly to the use of differing measures of MVPA. A national survey of youth in NZ, which used accelerometry to objectively measure physical activity levels, found that 62% of females and 72% of males complied with the physical activity guidelines of at least 60 minutes per day of MVPA on most days of the week (Clinical Trials Research Unit, 2010). This stands in stark contrast to the self-reported physical activity of NZ youth from

another nationwide survey involving 8,500 participants, which found that only 9.6% of youth met the criteria of 60 minutes of MVPA per day (Clark et al., 2013). The latter survey also showed significant differences between genders in physical activity levels, with boys twice as likely as girls to meet the recommended daily levels (13.6% vs 6.3%). Research from overseas has raised similar concerns about children's levels of physical activity. A large accelerometer-based study conducted as part of the National Health and Nutrition Examination Study (NHANES) in the USA found that only 42% of 6-11 year old children and only 8% of adolescents met the 60 minute guideline for daily MVPA (Troiano et al., 2008). Similarly, accelerometer research as part of the Millennium Cohort Study in the UK found that overall only 51% of children engaged in 60 minutes or more MVPA per day, with girls (38%) being significantly less active than boys (63%; Griffiths et al., 2013).

These seemingly low levels of physical activity may contribute to the declining health status in youth that has been reported both in New Zealand and internationally. Between 1989 and 2000 the risk of a child in New Zealand being overweight increased by 2.2 times, while the risk of being obese increased by 3.8 times (Turnbull, Barry, Wickens, & Crane, 2004). Ministry of Health figures report that in the period 2007-2011 alone, the childhood obesity rate increased from 8% to 11% (Ministry of Health, 2013). This finding is mirrored in research from Victoria, Australia, which showed decreasing levels of physical activity between 1985 and 2001 in school aged children, corresponding to a significant increase in rates of obesity (Salmon, Timperio, Cleland, & Venn, 2005). These trends are particularly serious because physical activity behaviour and associated health habits that are formed early in life are likely to continue into adulthood (Freedman et al., 2005; Kjonniksen, Torsheim, & Wold, 2008). Also, children who are obese are more likely

to remain obese throughout their lives (Serdula et al., 1993), which places them at higher risk of chronic diseases such as type 2 diabetes and cardiovascular disease (Park et al., 2003).

On a national level, the economic costs of insufficient physical activity and associated diseases are considerable. In New Zealand it is calculated that the health care costs attributable to overweight or obesity were \$686 million in 2006 which equates to 4.5% of New Zealand's total health care spending (Lal, Moodie, Ashton, Siahpush, & Swinburn, 2012). In addition, the costs of lost productivity associated with premature mortality were estimated to be \$98 to \$225 million depending on the formula used in the calculation (Lal et al., 2012). The direct health-care cost of type 2 diabetes alone in New Zealand was estimated to be \$600 million in 2008, and this is predicted to increase to \$1.3 billion by 2017 (Ministry of Health, 2009). Due to the health burden and economic costs associated with insufficient MVPA there has been considerable research into environmental factors that might influence physical activity behaviours. Addressing such precursors to chronic disease at a young age has been promoted as a cost-effective strategy to reduce chronic illness and the associated costs to the health system (Ebbeling, Pawlak, & Ludwig, 2002; Waters et al., 2011).

There are a myriad of biological, environmental, and social variables that affect a child's health and development. One factor that has been relatively recently identified in the literature is exposure to greenspace. Greenspace is defined as any open piece of land that is publically accessible, contains no buildings, and is partly or completely covered with grass, trees, shrubs, or other vegetation (United States Environmental Protection Agency, n.d.). Time spent in greenspace presents

opportunities for children to engage in physical activity as they play, explore, move, and challenge themselves in a relatively unrestricted manner. This, in turn, can provide suitable conditions for children to gain increased competence in a variety of physical skills, improve their social connections, develop their cognitive abilities, and enhance their emotional wellbeing. Greenspaces may also provide opportunities for children to explore their boundaries and experience the consequences of risk-taking through unstructured play in a challenging environment (Louv, 2005).

## **1.2 Greenspace**

Greenspaces, as defined above, include parks, community gardens, school playgrounds, sports fields, and vacant land (United States Environmental Protection Agency, n.d.). Greenspaces provide ideal locations for children to be active, to socialise, and to explore in an unstructured way (Louv, 2005). Methods commonly used in the literature to identify greenspaces range from neighbourhood audits using visual identification to analysis of maps or aerial photographs and the use of satellite imagery. For research purposes, inclusion criteria such as a minimum size of the greenspace are often utilised to determine which spaces are included in the study (Tamosiunas et al., 2014). This section will review the literature concerned with the measurement of greenspace (Section 1.2.1), and that which has investigated the associations between greenspace exposure and physical health (Section 1.2.2). Also the body of research that has explored trends in children's greenspace exposure will be reviewed (Section 1.2.3).

**1.2.1 Measuring exposure to greenspace.** A limiting feature in the current literature is the lack of consensus in how greenspace should be defined and measured. As a result of this, measures of greenspace exposure vary greatly amongst existing

studies. Measures of greenspace exposure that have been used in research have included the percentage of the neighbourhood classified as greenspace (Mitchell & Popham, 2007), the number of greenspaces in the neighbourhood (Cohen et al., 2007), and the distance between the participant's residence and the nearest greenspace (Stigsdotter et al., 2010). A weakness shared by all these measures is that they do not account for individual differences in how people interact with their local environment or people whose exposure to greenspace takes place outside of their neighbourhood (e.g., people who walk in a park close to their workplace during their lunch break). Recently, advances in technology, such as portable GPS receivers combined with geographical information systems (GIS) and web-based interactive mapping, have allowed more precise measures of an individual's exposure to greenspace.

***Global Positioning System (GPS) receivers.*** GPS receivers record geolocational data based on signals received from an array of orbiting satellites, which transmit information about their position at specific time intervals. The GPS receiver detects these signals and calculates its distance from these known satellite locations. By comparing data from at least three satellites the GPS receiver can calculate its current location by triangulation. Recent improvements in technology have resulted in light-weight, low cost, and accurate GPS receivers, which has enabled them to be used as a research tool for objectively monitoring movement and location in a wide variety of subjects (Krenn, Titze, Oja, Jones, & Ogilvie, 2011). GPS data have been used in research to monitor individual travel patterns, record activity locations, and create personalised neighbourhood boundaries (Kerr, Duncan & Schipperjin, 2011). Studies have also combined GPS data with data from either accelerometers or heart rate monitors which allows investigations of the associations between different locations, times, and physical activity levels (Almanza, Jerett,

Dunton, Seto, & Pentz, 2012; Duncan, Badland, & Schofield, 2009; Kerr, Duncan, & Schipperjin, 2011; Wheeler, Cooper, Page, & Jago, 2010).

Despite allowing greater accuracy and objectivity in recording physical location data, GPS research is subject to its own methodological challenges. Measuring location via GPS over multiple days requires a substantial level of compliance from the participants as the devices need to be correctly worn, recharged, and cared for. A review of the literature noted that participant adherence decreased over time in longer term studies which may result in incomplete data being gathered (Krenn et al., 2011). Previous research has also noted technological constraints such as data storage, signal loss, and device battery life as causes of missing data (Rainham, Krewski, McDowell, Sawada, & Liekens, 2008). In locations that are indoors or in close proximity to buildings, the received signal quality may be degraded resulting in missing or spurious data being recorded (Thornton, Pearce & Kavanagh, 2011). Additionally, GPS receivers undergo an initialisation period when they are first turned on during which time the device acquires the required number of satellite signals necessary to triangulate its location. In this period the receiver may record inaccurate information (Duncan, Mummery, & Dascombe, 2007). Due to such data quality issues, GPS data has to undergo processing and ‘cleaning’ prior to analysis. The development of tools such as the Personal Activity Location Measurement System (PALMS) has helped to standardise and facilitate this data cleaning process (Oliver, Badland, Mavoa, Duncan, & Duncan, 2010). PALMS is a web-based application that can integrate the output data from GPS receivers, accelerometers, and heart rate monitors to allow statistical and spatial analysis of the combined data. GPS receivers record geospatial data and therefore require analysis by a GIS that can work with data in this form.



***Geographic Information system (GIS).*** A GIS is a computer software system designed to assemble, process, analyse, and display geographically referenced data (Butler, Ambs, Reedy, & Bowles, 2011). GIS analysis has been incorporated into much of the recent research investigating environmental variables such as greenspaces and other neighbourhood features (McLafferty, 2003). GIS systems create map outputs derived from spatially referenced data files. These are organised in layers, which each contain spatial information on a single environmental feature (e.g., road networks). In combination with individual location and activity data, such as that gleaned from GPS and accelerometry, GIS has been used successfully to test for associations between various geographical features and physical activity behaviours (Butler et al., 2011). GIS analysis can be affected by how environmental variables are computed, the resolution and accuracy of the available map data, and the methodology used in the analysis (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009; Charreire et al., 2010). Despite the fact that research has shown that the parameters used in the analysis can strongly impact upon the results of the analysis (Jago, Baranowski & Harris, 2006), there are currently no recognised standards for obtaining, cleaning, managing, and analysing GIS data (Forsyth, Schmitz, Oakes, Zimmerman, & Koepp, 2006).

Various ways of measuring both greenspace and the neighbourhood with GIS have been utilised in the research depending on the data available and the particular research questions under investigation. Greenspaces are most commonly defined in GIS by the borders of public parks and recreational areas (Comber, Brunsdon, & Green, 2008), with some studies utilising detailed maps that also distinguish garden areas and grassy backyards as greenspaces (Wheeler et al., 2010). Other research has

used the ‘greenness’ of an area as measured by true-colour satellite imagery as a measure of the area’s greenspace (Almanza et al., 2012). GIS has also been used to assess measures of greenspace accessibility such as the distance to a greenspace from participants’ homes (Coombes, Jones, & Hillsdon, 2010), while other studies have assessed the quality of a greenspace as defined by its GIS-measured features. (Hillsdon, Panter, Foster, & Jones, 2006). Likewise research into the neighbourhood environment has frequently utilised GIS in both measurement and analysis of variables. The neighbourhood has also been defined in a variety of ways in the literature as will be explored in Section 1.3.3.

***Web-Based Interactive Mapping.*** Recent advances in technology, such as online mapping services have provided researchers with a powerful tool to record travel information and facilitate accurate recall of participant’s local environments. Using publically available software such as Google Maps™ (<https://www.google.co.nz/maps>), detailed maps or satellite images of the neighbourhood can be used in conjunction with a semi-structured interview to assist participants in identifying and recording relevant features and travel routes. One such web-based interactive mapping tool is softGIS (Brown & Kytta, 2014), an application that allows researchers to create surveys that combine map-based and traditional survey questions. Using portable devices such as iPads or smart phones respondents can answer the questions by marking places, routes, and areas on web-based maps. SoftGIS software has been used in research on children to identify children’s perception of environmental threats, engagement in active transport, and territorial range (Kytta, Broberg, & Kahila, 2012).

The Visualization and Evaluation of Route Itineraries, Travel destinations and Activity Spaces (VERITAS) is another online mapping tool which provides a method of exploring an individual's self-reported movement through their neighbourhood (Chaix et al., 2012). Like softGIS, VERITAS is a computer-assisted questionnaire which combines web-based mapping with survey questions to facilitate accurate geolocation of individuals' activity places, routes between locations, and relevant areas such as their experienced or perceived neighbourhoods. The survey aspect also allows collection of information on potentially mediating variables such as mode of transport, travel companions, and perceived barriers in access to locations (Chaix et al., 2012). VERITAS surveys can be customised to focus on a wide range of variables, activities, and time periods which makes it a well suited tool for research into neighbourhood and greenspace exposures. Although no research yet exists which has specifically measured children's exposure to greenspace using VERITAS, it has been used to investigate active travel and perceived neighbourhood boundary in a large survey of adolescents in New Zealand (Hinckson et al., 2014). Unlike GPS tracking, which of practical necessity only yields data from a moderately short term monitoring period, VERITAS can be used to assess the significance of locations and travel routes over longer periods. This allows a measure of chronic environmental exposure, which may enhance or serve as a comparison to GPS data. All information entered into VERITAS is geocoded, allowing destinations, trip routes, and neighbourhood boundaries to be imported into a GIS to allow for more detailed analysis.

**1.2.2 Greenspace exposure and physical health.** There is a large body of research indicating that an individual's exposure to greenspaces is positively correlated with improvements in many measures of physical health. Most of this research, however, has investigated adult populations, and comparatively little is

known about the associations between greenspace exposure and children's health. In adults, a wide range of health outcomes have been shown to be influenced by levels of greenness in local environments. These include respiratory disease (Richardson & Mitchell, 2010; Villeneuve et al., 2012), migraines (Maas et al., 2009), musculoskeletal complaints (Maas et al., 2009), cardiovascular disease (Pereira et al., 2012), birth outcomes (Dadvand et al., 2012), some cancers (Li et al., 2008), infectious diseases (Maas et al., 2009), and diabetes mellitus (Astell-Burt, Feng, & Kolt, 2014a). Levels of neighbourhood greenness have also been associated with increased life expectancy and decreased all-cause mortality (Jonker, van Lenthe, Donkers, Mackenbach, & Burdorf, 2014; Takano et al., 2002). A large study on an adult population from the Netherlands ( $N = 345,000$ ) found significant variations in disease prevalence between individuals from neighbourhoods with differing amounts of greenspace. After controlling for socio-economic status, individuals living in less-green neighbourhoods were found to have disease prevalence rates that were at least 20% higher in 11 major categories of disease (Maas et al., 2009).

A similar outcome was found in another large study ( $N = 250,782$ ) on an urban adult population that analysed the relationship between self-reported health status and the amount of greenspace in their neighbourhood environment (Maas et al., 2006). This study used the GIS measured percentage of greenspace in a 1 km and 3 km radius around their home address as a measure of the quantity of greenspace in the participants' environment. A positive association between neighbourhood greenness and the reported health of residents was detected. In areas where 90% of the environment around the home was greenspace, only 10.2% of respondents reported feeling unhealthy, whereas in neighbourhoods where only 10% of the local environment was greenspace, 15.5% of the respondents reported poor health (Maas

et al., 2006). Although reliant on self-reported measures of physical health, this study had the advantage of using an objective measure of the local greenness and also included neighbourhoods of differing socioeconomic status. The trend towards greater self-reported health with increased neighbourhood greenspace was present in all socioeconomic groupings. Another large study using 2001 census data from England also examined the relationship between the percentages of land in an area classified as greenspace and self-reported health status (Mitchell & Popham, 2007). This study found an overall significant positive relationship between percentage of neighbourhood greenspace and perceived health; however, the authors noted that this relationship was complex and significantly mediated by socioeconomic status and neighbourhood urbanity. In higher income areas there was no association between greenspaces and health and in lower income suburbs a higher proportion of greenspace was associated with worse health (Mitchell & Popham, 2007).

A large observational study, covering urban areas of New Zealand, investigated the relationship between neighbourhood level greenspace and risk of mortality from cardiovascular disease and lung cancer. The study used mortality data from the New Zealand Ministry of Health paired with GIS-based analysis of useable greenspace in urban areas. Health status and residential address data from 1.5 million people was included in the analysis. This study controlled for age, sex, socioeconomic deprivation, smoking, air pollution, and population density. After adjusting for these possible confounds, this study found no association between total neighbourhood greenspace and mortality data (Richardson, Pearce, Mitchell, Day, & Kingham, 2010).

Accessibility of greenspaces in the participant's local environment has also been used as a proxy measure of greenspace exposure. A large scale ( $N = 11,238$ ) survey from Denmark found an association between the proximity of a respondents house to a greenspace and both their health related quality of life and perceived stress levels (Stigsdotter et al., 2010). Respondents who lived more than one kilometre from the nearest greenspace reported poorer health and lower health related quality of life than those who lived closer. This survey adjusted for variables such as ethnicity, cohabitation status, and education, but did not adjust for socioeconomic status which could be a potential confound (Dai, 2011). It is also limited by its reliance on self-report data for all variables including distance to nearest greenspace (Stigsdotter et al., 2010).

Emerging research has also highlighted a potential health risk related to higher levels of greenspace exposure. A recent survey of 267,000 Australians reported a positive association between neighbourhood greenspace and skin cancer incidences ( $p < 0.001$ ). Once adjusted for various known risk factors, individuals living in an area with >80% greenspace had a 9% higher incidence of skin cancer than those in neighbourhoods with 0-20% greenspace. This study showed that individuals living in neighbourhoods with higher levels of greenspace spent more time outside and engaged in greater amounts of MVPA however only 1.6% of the association with skin cancer was mediated by MVPA (Astell-Burt, Feng, & Kolt, 2014b).

Possible causative or mediating mechanisms behind greenspace exposure and physical health include the provision of physical activity opportunities, improved air quality, facilitation of social contact, and the restorative psychological effects of nature (Kuo, 2015). Although, as outlined in this section, the association between

health outcomes and greenspace exposure has been investigated by many large studies, the validity of this research is limited by reliance on measures of local availability or accessibility of greenspace as a surrogate for individual's greenspace exposure. It is unknown whether these proxy measures have any correlation with an individual's actual exposure to greenspace (Lachowycz, Jones, Page, Wheeler, & Cooper, 2012). It has been recognised that environmental factors such as the quality and accessibility of greenspace, and individual determinants such as gender, ethnicity, socioeconomic status, and the perception of safety are likely to all influence an individuals' exposure to greenspace (Lee & Maheswaran, 2010). Also, although an individual's age is another factor which has been proposed as an influence on their exposure to greenspaces (Lee & Maheswaran, 2010), the literature in this area has universally considered adult populations. Whether similar associations would be found in a younger population remains unknown. There is a need for research that investigates associations between children's exposure to greenspaces and their physical health. This is perhaps particularly important as evidence shows that the amount of time that children spend in greenspaces has been influenced by recent social and environmental changes. The literature which has investigated these trends will now be reviewed in the following section.

**1.2.3 Current trends in greenspace exposure.** Shifts in the social and environmental influences on children over the last few decades have been associated with significant changes in how children spend their time. The general trend of these changes has been towards indoor and sedentary activities and away from outdoor recreational activities. According to a time report on American school age children, the average time spent outdoors has reduced from 1 hour 40 minutes per week in 1981/2 to just 50 minutes per week in 2002/3 (Juster, Ono, & Stafford, 2004). This

survey also recorded a corresponding increase in the time spent in indoor, sedentary activities such as computer use, and homework. These data are consistent with a 1997 survey of American school children which showed that 9-12 year olds only spent an average of 42 minutes a week outdoors (Hofferth & Sandberg, 2001).

Explanations that have been proposed for this trend away from outdoor play and hence greenspace exposure include, increasing urbanisation and societal changes in perceptions of the risks associated with outdoors and unsupervised activities. Globally there is a strong trend towards increased urban living, with over half of the global population now living in cities and daily environmental contact with greenspaces becoming rarer (UNFPA, 2007). There is evidence that in urban locations the area of greenspaces declines as the population of the urban area increases. In a study from the UK, researchers compared GIS maps of urban land in 2000 with GIS modelling of data extracted from aerial photographs taken in 1975. This enabled comparisons in land use over a 25 year period. This study found that there was a significant loss of greenspace coverage, from 38% of the region in 1975 to 33% in 2000, while there was a corresponding increase in coverage for the built environment from 54% to 61% over the same time period (Pauleit, Ennos & Golding, 2005). These changes were correlated with increased population in this urban region. It is therefore likely that the global trend towards increasing urban populations has, and will continue to have, an associated trend towards reduced greenspace exposure for urban dwellers.

A second factor which may underlie the decreasing exposure that children have to greenspaces is the recent rise of what has been referred to as the 'risk averse society' (Lester & Maudsley, 2007). According to Lester and Maudsley (2007)



recent decades have seen a change in the culture of parenting whereby the distinctions between 'risk' and 'uncertainty' and 'good risk' and 'bad risk' have become blurred. An analysis of childhood in the UK by Hocking and Thomas (2003) examined the impact of this increasing risk aversion on children's lives. They found a growing 'privatisation' of childhood, with the immediate family taking all the responsibility for looking after children and an associated reduction in any forms of community responsibility. This risk averse worldview affected parent's decisions on factors such as how much independence their children were permitted in unsupervised play, and what environments were considered safe to play in. It has been proposed that parents may base these decisions on unfounded fear and what amounts to an over-estimation of risk (Spilsbury, 2005). This has been corroborated by the results of a survey of 830 mothers of 3-12 year olds in the USA. This survey compared the mother's childhood play patterns with those of their children and found that 70% of the mothers reported playing outside everyday compared with 31% of their children (Clements, 2004). This survey identified crime and safety concerns as well as an increase in indoor entertainment options (e.g., computers and video games) as being the key reasons for children spending less time playing outside and hence less time in greenspace.

Other research has found that parental concerns about road safety and potential risks posed by 'strangers' are the main stated reasons why children are not permitted to travel independently (Carver, Timperio & Crawford, 2007). These safety concerns have led to a decrease in children's independent travel in the neighbourhood environment (Fyhri, Hjorthol, Mackett, Fotel, & Kytta, 2011) which in turn is likely to be associated with a reduction in greenspace exposure. This was shown to be the case in recent research from Australia which found that children who are permitted

to engage in independent active transport are more likely to spend time in greenspaces (Veitch et al., 2014). Children in this study who had parks within walking distance of their homes were significantly more likely to visit these parks at least once a week if they were allowed to walk or cycle there independently, compared with those who were not permitted to travel unaccompanied by an adult. Both environmental changes, such as the increase in urbanisation, and social changes, such as increased parental risk aversion have been implicated as causative factors contributing to children's reduced exposure to greenspaces. It is likely that this reduced exposure to greenspace is in turn having an effect on children's health-related behaviours such as engagement in physical activity.

### **1.3 Physical Activity**

Children's engagement in physical activity is one factor which has been investigated for its association with greenspace exposure. Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure. (World Health Organisation, n.d). Physical activity includes exercise as well as other activities that involve bodily movement and are done as part of working, active transport, playing, recreation or household chores. (World Health Organisation, n.d.). As outlined in Section 1.1, a large body of research has shown that physical activity is associated with numerous health benefits in children. This section will review the ways that physical activity is typically measured (Section 1.3.1), the relationship between physical activity and greenspace exposure (Section 1.3.2), and the associations between physical activity and the neighbourhood environment (Section 1.3.3).

### **1.3.1 Measuring physical activity**

*Subjective measures.* Many different measures of physical activity have been used in physical activity research. The simplest and most cost-effective measures of physical activity are subjective, self-report questionnaires. Because of their ease of implementation, questionnaire measures are frequently used in physical activity research especially those involving large populations (Welk, 2002). These measures may be self-administered or completed with the help of an interviewer. There is a large number of questionnaire measures that have been used in the literature and the reported validity and reliability of these different measures varies widely. Studies that have investigated the correlation between self-report questionnaires and objective observations of physical activity in children have reported correlations between  $r = -0.10$  and  $r = 0.88$  (Sirard & Pate, 2001). In research on younger or non-verbal children, sometimes proxy reports involving the child's parents, caregivers, or teachers have been used as a measure of activity. There is a paucity of research investigating the validity of these proxy measures, however the studies that have been published have found either no significant correlation (Noland, Danner, Dewalt, McFadden, & Kotchen, 1990) or weak correlations (Manios, Kafatos, & Markakis, 1998) between directly observed physical activity and parent or teacher reported activity levels. Activity diaries are another self-report measure which has been frequently used in the literature. These are considered to be one of the most accurate subjective measures in adult populations, however their validity and reliability has not been ascertained in juvenile subjects (Sirard & Pate, 2001). Subjective measures are relatively inexpensive and simple to implement. They provide a measure of physical activity suitable for large studies while minimising the burden to both participants and researchers. The limitations of these measures stem from their subjective nature; they are vulnerable to

social desirability bias in reported activity, memory recollection errors, and deliberate misrepresentation of activity (Welk, 2002).

***Objective measures- Accelerometry.*** The recent development of light, portable, and accurate accelerometers has given researchers access to a well-tolerated, accurate, and objective measure of physical activity. An accelerometer is a portable device that detects and records acceleration in one or more orthogonal planes. By recording objective movement data they can yield insights into the intensity, frequency, and duration of physical activity (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). Accelerometer sensors collect samples at a predefined frequency usually between 10-100Hz. These samples are summated over a user-specified time sampling period referred to as an ‘epoch’. These are then converted into an activity ‘count’ which provides a measure of movement intensity (John & Freedson, 2012). Various cut points in count intensity have been used in the literature to classify the intensity of the physical activity as either sedentary, light, moderate, or vigorous (Oliver et al., 2011). The use of different cut points to differentiate between these categories has been the subject of much research, and various cut point schema have been developed depending on the nature of the research, the device used, and the population under study. However, there is currently no clear consensus as to which cut point definitions constitute best practice for accelerometer research in any population (Troost, Loprinzi, Moore, & Pfeiffer, 2011). Despite these limitations, accelerometer measures of physical activity have well established validity and reliability against other objective measures (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008; Puyau, Adolph, Vohra, & Butte, 2002). Accelerometers have become widely used in research into free-living physical activity in both adults and

children due to their portability, convenience, and ability to enable accurate activity monitoring over longer durations and in larger samples.

**1.3.2 Children's physical activity and greenspace exposure.** Greenspaces, by their very nature, are generally assumed to be conducive to physical activity. Evidence for this assertion comes from the work of Fjortoft and Sageie (2000) in their analysis of a forest area in Norway that was used as an outdoor kindergarten for five to seven year olds. Using GIS and environmental assessment tools they analysed how children's play related to various landscape features such as vegetation and topography. The study showed that this natural environment provided a wide variety of settings for different types of physically active play amongst children. A follow-up study (Fjortoft, 2001), compared children at this kindergarten ( $n = 46$ ) with a control group comprising of children from different kindergartens in the same district ( $n = 29$ ). The children from the experimental kindergarten were given the opportunity for unstructured play in the forest area for one to two hours per day. At the end of nine months, children in the outdoor play group had significantly greater improvements in eight out of nine standardised physical tests incorporating, fitness, strength, balance, and co-ordination tasks (Fjortoft, 2001).

A growing body of literature has investigated the relationship between the amount of exposure an individual has to greenspaces and their engagement in physical activity. This body of literature has produced varying conclusions. A systematic review including 50 quantitative studies on the association between greenspace availability and physical activity was published in 2011 (Lachowycz & Jones, 2011). Forty one of these studies relied on participant self-report as a measure of physical activity, while nine used accelerometry as an objective measure of

activity. Twenty of the 50 studies (40%) reported a positive relationship between greenspace exposure and physical activity. Twenty eight studies (56%) found either weak or mixed evidence for an association, and two studies (4%) reported a negative association between greenspace and physical activity (Lachowycz & Jones, 2011). This review also highlighted the fact that there exists considerable variation in how greenspace exposure is measured, with some studies measuring the distance from a participants house to the nearest greenspace, others using a percentage of greenspace in a defined local area, and others using the number of greenspaces in the local area. The authors of this review noted that these crude measures of greenspace did not give consideration to the quality or other features of such areas. They also reported that very few of the studies had measured individual use of greenspace and recommended the use of GPS technology in future research to help address this.

A nationwide trial from the United States investigating physical activity levels in adolescent girls (Trial of Activity in Adolescent Girls: TAAG) examined the association between proximity, type, and features of public parks and engagement in physical activity. They found that the number and features of parks in the half-mile zone surrounding the participant's home address was positively associated with their level of MVPA. Each additional park within the half mile neighbourhood buffer was associated with an increase in MVPA by 2.8% (Cohen et al., 2007). In a similar survey, Wolch et al (2010) collected data from 3,173 Californian children over an eight year period. They discovered that living within 500 meters of a public park was significantly associated with having a lower BMI at age 18. This association was more pronounced in boys than girls.

In contrast to these largely positive results, Ord, Mitchell and Pearce (2013) investigated the extent to which locally available greenspace was associated with total physical activity and also what proportion of that activity specifically takes place in greenspaces. This study used survey data from 3,679 adults living in urban areas of Scotland. They explored the relationship between the percentage of the participant's neighbourhood that was classified as greenspace and the total physical activity the participant reported. The researchers also enquired into the amount of this physical activity that specifically took place in greenspaces. This study found no relationship between the proportion of neighbourhood greenspace and residents total physical activity levels or between neighbourhood greenspace and reported physical activity that occurred within greenspaces. This study was conducted with adult participants, whether these findings are applicable to children is unknown.

In an effort to measure exposures to greenspace with greater reliability and validity, GPS devices have been used in research to provide objective, high resolution data on individuals' location and movement. There have been several recent studies investigating children's activity patterns which have utilised this methodology. One such study used GPS and accelerometers to measure children's activity levels and locations during free time (Almanza et al., 2012). They compared the data from children who lived in a neighbourhood which was designed with consideration given to improving access to greenspace (Smart Growth), and those who lived in a socioeconomically similar neighbourhood which had not been designed to maximise greenspace accessibility (Conventional). They found that children from both neighbourhoods were significantly more likely to engage in MVPA when they were in a greenspace. Children from the Smart Growth community were 39% more likely to engage in MVPA when in greenspaces,

compared to a 34% increase in likelihood of MVPA for children from the conventional neighbourhood. Consistent with other research, this study showed that boys were more likely than girls to be physically active in greenspace. However other variables such as age, race, socioeconomic status, and BMI were not associated with the likelihood of MVPA. Individual level analysis showed that children who experienced greater than 20 minutes of exposure to greenspaces per day engaged in nearly five times the daily rate of MVPA than those children with less than 1.5 minutes of daily exposure to greenspaces. The authors noted that approximately 50% of children in the study had less than 1.5 minutes per day of exposure to neighbourhood greenspaces (Almanza et al., 2012).

A similar study from the UK also used GPS and accelerometry to monitor children's after school activity levels (Wheeler et al., 2010). This study found that children spent 13% of their after school time outdoors, during which they accumulated 35% of their afterschool MVPA. Only 2% of their afterschool time was spent in greenspaces, but for boys this accounted for 9% of their total MVPA and for girls 6% of their MVPA. Similar to Almanza et al (2012) this study showed that overall children were 37% more likely to engage in MVPA when in a greenspace compared to an outdoor non-greenspace. This likelihood was strongly influenced by gender, with boys being 41% more likely to be active in greenspaces, whereas girls were only 10% more likely to engage in MVPA (an increase which was not statistically significant). Unlike Almanza et al (2012) this study found evidence for reduced likelihood of MVPA in greenspace for children with higher BMI.

Further evidence for the association between children's exposure to greenspace and levels of physical activity is provided by a large UK study based in the city of



Bristol which collected valid GPS and accelerometer data from 614 secondary school children (Lachowycz et al., 2012). This study found that physical activity in greenspaces made a substantial contribution to the total amount of MVPA that participants accrued. During after-school time, 34% of outdoor MVPA took place in greenspaces, and in the weekend, 46% of outdoor MVPA occurred in greenspaces. Although these are considerable proportions it should be noted that they represent quite low actual figures. Children in this study accrued most of their daily MVPA indoors and the actual amount of MVPA in greenspace was relatively low (means of 2.4 minutes per weekday after-school, and 3.5 minutes per weekend day) (Lachowycz et al., 2012).

**1.3.3 Children's physical activity and the neighbourhood environment.** The neighbourhood is the environmental context in which children spend the majority of their time (Loebach & Gilliland, 2014), therefore understanding the influence that this environment exerts on their health behaviours may help us better understand and influence children's health outcomes. The neighbourhood potentially provides a supportive environmental context for physical activity, social interaction, and development of autonomy; however recent literature has reported a decrease in children's independent mobility within the neighbourhood (Bhosale, Duncan, Schofield, Page & Cooper, in press; Fyhri et al., 2011; Pooley, Turnbull, & Adams, 2005). Empirical research shows that children are spending more of their time in indoor sedentary activities than in the past, and correspondingly less time active in their wider neighbourhood environment (Fagerholm & Broberg, 2011; Wridt, 2010; Veitch, Salmon, & Ball, 2008; Villanueva et al., 2012). In response to these trends away from neighbourhood physical activity, a significant body of research has developed investigating the influence of both the physical and social environment on

children's neighbourhood activity levels. Physical neighbourhood variables that have been investigated in this literature include access to parks and recreational facilities, land-use mix, traffic speed and volume, residential density, street connectivity, the presence of sidewalks, pedestrian safety structures, crime-related safety, and the presence of vegetation (Davison, & Lawson, 2006; Ding, Sallis, Kerr, Lee, & Rosenberg, 2011).

Studies that have sought to relate these physical neighbourhood attributes to children's physical activity have produced inconsistent findings. A comprehensive review of this literature concluded that the consistency of associations between youth physical activity and neighbourhood attributes was strongly influenced by how the different variables were measured (Ding et al., 2011). This review included 65 papers, 86% of which were published since 2004. The authors divided up the outcome measures into subjective measures, which included both perceived neighbourhood characteristics and self-reported physical activity, and objective measures, which encompassed both objectively measured neighbourhood variables and physical activity. This allowed them to investigate how the choice of measurement tool influenced the findings. When neighbourhood attributes were measured objectively and physical activity measured by self-report, associations were found in 66% of studies. However significant associations were only present in 33% of studies which employed objective measures for both neighbourhood characteristics and physical activity (Ding et al., 2011). Physical activity and neighbourhood environment associations were generally weaker in those studies that measured the environmental attributes subjectively. Perceived neighbourhood characteristics were related to reported physical activity in 34% of studies and only

related to objectively measured physical activity in 12% of studies (Ding et al., 2011).

A recent study of 4-13 year old Australian children ( $N = 4,983$ ) investigated the associations between self-reported physical activity and screen time and objectively measured neighbourhood greenspace (Sanders, Feng, Fahey, Lonsdale, & Astell-Burt, 2015). This study found that neighbourhood greenspace was positively related to physical activity and negatively related to sedentary behaviour for boys. For every 10% increase in neighbourhood greenspace, boys showed a 2.3 min reduction in weekend television viewing ( $p < 0.05$ ) and 7% and 9% greater odds of meeting physical activity guidelines on weekdays and weekends respectively ( $p < 0.05$ ) (Sanders et al., 2015). However, these relationships between local greenspace, physical activity, and screen time were only evident amongst younger boys and not present in boys aged nine and over. No significant relationship between physical activity and neighbourhood greenspace were found for girls in this study.

Children's relationship with their neighbourhood environment has also been influenced by many of the same trends that have already been identified as influencing their exposure to greenspaces (Section 1.2.3). These trends are evident in factors such as parenting beliefs, family structures, entertainment choices, and increases in technology in the home. These changes in children's social environment have affected the quantity, type, and location of children's activity. Technological changes have led to an increase in sedentary, home-based entertainment options such as computers and television which now occupy an increasing amount of children's leisure time (Clements, 2004; Karsten, 2005; Witten, Kearns, Carroll, Asiasiga, & Tava'e, 2013). Increased parental concern, as evidenced by the reported rise of

‘helicopter parenting’ (Somers & Settle, 2010), has also led to indoor supervised activity being seen as more desirable, and outdoor activity in the wider neighbourhood being seen as ‘risky’ (Clements, 2004; Gray, 2011; Valentine & McKendrick, 1997). Social changes such as children’s increased involvement in structured activities and increases in households where both parents work may have also led to children spending less free time in the neighbourhood and more time indoors, or being driven to locations outside their neighbourhood (Copperman & Bhat, 2010; Gray, 2011; Loebach & Gilliland, 2014; Mikkelsen & Christensen, 2009).

*Measurement of the neighbourhood environment.* There is considerable variation amongst the existing literature as to what defines the ‘neighbourhood’. Many studies have used administrative neighbourhood boundaries such as those defined by post codes or local body jurisdictions (Giles-Corti & Donovan, 2002; Kavanagh et al., 2005). The advantages of using such definitions is that these boundaries are often used by government agencies for recording statistics on crime, poverty, socioeconomic status, or local facilities, and thus any new measures recorded can be directly compared with existing data. However, there is evidence from studies that have asked participants to map their own perceived neighbourhood boundary, that neighbourhoods, as defined by administrative borders, can differ significantly from resident’s self-described neighbourhood (Coulton, Korbin, Chan, & Su, 2001; Hume, Salmon, & Ball, 2005; Veitch, Bagley, Ball, & Salmon, 2006). Therefore, although administrative neighbourhoods are convenient it is possible that they do not adequately capture the residents actual lived environment and therefore may not be suitable for research investigating environmental exposures.

Alternatively, defining the neighbourhood by proximity to the participants' home addresses yields a consistently sized neighbourhood which is specific to each participant. This approach has been used in much of the research on neighbourhood-level influences on health, however there is little consensus amongst this literature as to what constitutes an appropriate boundary to the neighbourhood (Giles-Corti, Timperio, Bull, & Pikora, 2005). As a result of this, neighbourhood has been variously defined as a radius around the home address of 400 meters (Pikora, Giles-Corti, Bull, Jamrozik, & Donovan, 2003); 800 meters (Austin et al., 2005); 1 kilometre (Frank, Andresen, & Schmid, 2004); 0.5 miles (Addy et al., 2004); and 2 miles (Jeffery, Baxter, McGuire, & Linde, 2006). Ball, Timperio, and Crawford (2006) suggest that in the absence of a recognised 'optimal' neighbourhood definition, the measure used should vary depending on the population age, residential density, and the type of behaviours that are being investigated in the research. Children's neighbourhoods may require different definitions than those for adults due to differences in ability to travel, environmental features of interest, and behavioural autonomy. This has been corroborated by research which monitored 11-12 year old children's independent travel and found that their 'neighbourhood range' could be defined by a radius of anywhere between 400 and 1600 meters from their home (Loebach & Gilliland, 2014).

#### **1.4. Cognitive development**

Cognition is a general term that describes a number of different mental processes including attention, executive function, perception, pattern recognition, memory, working memory, intelligence, reasoning, and academic achievement (Tomprowski, Davis, Miller, & Naglieri, 2008). Development of these cognitive faculties largely takes place in critical periods throughout infancy, childhood, and

adolescence. The measurement of cognition in children and adults is a well-established field, and a significant body of literature exists supporting various approaches (Hodges, 2007). However, computerised neurocognitive testing applications represent a relatively new approach to the testing of cognition. The research concerning this measure of cognition will be reviewed in Section 1.4.1. Many factors which might influence children's cognitive development have also been researched. In keeping with the focus of this thesis, this chapter will review the research investigating the associations between cognition and physical activity (Section 1.4.2) and cognition and greenspace exposure (Section 1.4.3).

#### **1.4.1 Measuring cognitive development**

*Computerised Neurocognitive Testing (CNT).* Computerised neurocognitive testing applications allow standardised psychological tests of neurological and cognitive function to be administered by a computerised software system. These testing methods have been developed to meet the needs of researchers and clinicians who require accurate testing which can measure mild degrees of neurocognitive impairment in a relatively efficient, quick, and cost-effective manner. Compared to conventional psychological testing, CNT's allow complete consistency in administration and scoring, elimination of human error from continuous measures such as reaction time, and the ability to automatically randomise question order (Gaultieri, 2004). They can be used to test a large number of subjects concurrently which reduces the time burden of testing for clinicians and researchers. Research has demonstrated the feasibility to CNT, its acceptability to subjects, and the reliability of the data generated through CNT (Gaultieri, 2004; Paul et al., 2005; Williams et al., 2005).

CNS Vital Signs (CNSVS; [www.cnsvitalsigns.com](http://www.cnsvitalsigns.com)) is a CNT system which consist of an array of standardised neurocognitive tests. The CNSVS test battery consists of seven tests that are frequently used in neuropsychological analysis and have well established reliability and validity. The tests cover a number of cognitive domains and are known to be sensitive to mild levels of cognitive impairment.

- The visual memory (VIM) test is adapted from the Rey Visual Design Learning test and the verbal memory test (VBM) is adapted from the Rey Auditory Learning Test (Delaney, Prevey, Cramer, & Mattson, 1992; Wilhelm, 2004). VBM and VIM scores are combined to generate an overall memory domain score.
- The Finger Tapping Test (FTT) is used to assess the integrity of the neuromuscular system. It involves the subject tapping the index finger of one hand as rapidly as possible on a selected computer key for a period of 10 seconds. This test is three to six times repeated on each hand. Because finger tapping is a basic biomechanical task it's used as a simple, neurologically driven motor task to assess impairments in the motor system or lateralised brain dysfunction (Morrison, Gregory & Paul, 1979).
- Symbol digit coding (SDC) is based on the Symbol Digit Modalities Test. The subject has to substitute a predetermined symbol for a digit under time pressure (Sheridan et al., 2006). The results from the SDC and the FTT are combined to generate a score for psychomotor speed.
- The Stroop test (ST; Stroop, 1935) asks the participant to discriminate between colour adjectives (eg. red, yellow, and blue) and the colour of the text that the words are written in. The Stroop test can be conducted in different ways to generate complex and simple reaction times and a domain score can be calculated that reflects the subject's information processing speed.

- The Shifting Attention Test (SAT) assesses the subjects ability to shift from different instructions accurately and rapidly (Gaultieri & Johnson, 2006). The results from the SAT are combined with those of the Stroop test to generate a domain score for cognitive flexibility.
- The Continuous Performance Test (CPT) is a measure of sustained attention (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). The results from the CPT, the SAT and the Stroop test are used to generate a domain score for 'complex attention'.

CNSVS uses randomised presentation of stimuli, and draws from a large database of test questions which makes serial testing possible. It records reaction times accurate to the millisecond. It can be taken unassisted by any child with an eight year old reading level, and the visual display can be read by those with colour-blindness. The tests are completed by pressing keyboard keys using a minimum number of keys so that keyboard skill has a minimal influence on performance. The battery of tests take about 30 minutes to complete and a report is generated automatically by the software as soon as testing is finished (Gualteiri & Johnson, 2006). CNSVS has shown similar psychometric properties to the standardised versions of these tests when tested on subjects with mild neurocognitive impairments (Attention deficit/hyperactivity disorder, mild traumatic brain injury, and early dementia). Amongst these subjects CNSVS has shown to have good levels of test-retest reliability, concurrent validity, and discriminant validity (Gualteiri & Johnson, 2006).

**1.4.2 Children's cognitive development and physical activity.** Although there are myriad factors which can influence cognitive development, it has been shown that physical activity plays a key role in establishing and strengthening these fundamental



mental processes (Tompsonowski, Lambourne, & Okumura, 2011). This evidence comes from both correlational and experimental studies. A large survey of American school children ( $N = 5,316$ ) analysed the relationship between the number of minutes spent in physical education per week and academic results in standardised mathematics and reading tests. This study found a small but significant positive association between increased time in physical education and improved academic performance in primary school aged girls. However this study showed no such association for boys (Carlson, Fulton, & Lee, 2008). Another large American study ( $N = 1,989$ ) found that higher levels of aerobic fitness, as measured by 1-mile run time, were associated with higher standardised test scores in maths, reading, and language (Roberts, Freed, & McCarthy, 2010). A strength of this study was that it controlled for possible confounds such as parents educational attainment, age, socioeconomic status, gender and ethnicity. In contrast to these results, a survey of almost 7,000 Canadian children found no relationship between the self-reported physical activity level and their performance in standardised academic tests (Tremblay, Inman, & Willms, 2000). However a weakness of this study was its reliance on the child's self-report as an indicator of their activity level. As has been previously discussed in Section 1.3.1, evidence shows that there is a highly variable association between self-reported and objectively measured physical activity (Sallis, 1991; Sirard & Pate, 2001).

A meta-analysis by Sibley and Etnier (2003) reviewed the relationship between children's physical activity and cognition from 44 studies. They concluded that increased physical activity was positively associated with improvements in cognitive function (Effect size,  $g = 0.32$ ;  $p < 0.05$ ). Of the studies included in this review, only nine were published in peer-reviewed journals and the authors acknowledged that the methodological rigour of some of the included studies was questionable.

However, the reported positive association between physical activity and cognitive function has been supported by a more recent review (Tompson et al., 2008). This review only included studies published in peer-reviewed journals and concluded that children who participate in long-term exercise programmes show significant improvements in cognition, particularly in tests of executive function.

The results from experimental studies show variation depending on what aspect of cognitive development is measured. Studies that have measured the effect of exercise interventions on general intelligence have mostly found no effect (Keeley & Fox, 2009). However, interventions that have measured executive function and academic achievement have generally shown beneficial responses to interventions that promote physical activity. For example a three year long randomised controlled trial in which the experimental group engaged in 90 min/week of MVPA during the school day found that children in this intervention group performed better in standardised academic tests than children in the non-exercise control group. (Donnelly et al., 2009). In a similar study, researchers randomised 171 children aged seven to eleven into either a control group or exercise groups that performed either 20 or 40 minutes of daily MVPA for 13 weeks (Davis et al., 2011). This study showed a dose-dependent benefit of exercise on standardised academic test results. Also these researchers utilised functional MRI (fMRI) imaging to show that children in the exercise groups showed an increase in brain activity in the prefrontal cortex during executive function testing. This improvement also followed a dose-dependent response to the exercise intervention with those in the 40 min MVPA/day group exhibiting greater increases in cortical activity than those in the 20 min MVPA/day group. All of these experimental studies have utilised specific, structured physical

activity in the form of aerobic exercise programmes. It is unknown if unstructured physical activity, such as free play, might show the same effects.

**1.4.3 Children's cognitive development and greenspace exposure.** Many aspects of children's social, and cognitive development can be influenced by the environments that children are exposed to (Brooks-Gunn, Duncan, Klebanov, & Sealand, 1993). It has been theorised that greenspaces provide an environment strongly supportive of positive cognitive development (Strife & Downey, 2009). Indeed, some studies have found that greenspace exposure as minimal as a natural view from a window can be shown to correlate with measures of cognition. Tennessen and Cimprich (1995) found that college students with natural views from their dormitory rooms had better attentional capacities than those with built views from their rooms. Similarly, Faber-Taylor, Kuo, and Sullivan (2002) investigated the association between children's directed attention and the 'greenness' of the views from their apartments. Children from three architecturally identical inner city apartments were tested on concentration and impulse control and their results were correlated with their parent's ratings of the 'naturalness' of the view from their apartment windows. For girls the greenness of the view accounted for 20% of the variance in directed attention. However this study found no association between these variables for boys. Conversely, other research on behavioural and attentional problems in children found that the likelihood of a boy exhibiting hyperactivity symptoms were positively associated with the distance between his house and the nearest greenspace (Markevych et al., 2014). A small pilot study on children ( $N = 12$ ) with a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD) has shown that these subjects perform better on concentration tests when in a natural, as opposed to a built, environment (Van den Berg & Van den Berg, 2011). A further exploratory study has been conducted on

children from low-income families ( $N = 17$ ) who were moved from a housing estate with low levels of natural vegetation to another housing estate in a significantly 'greener' neighbourhood (Wells, 2000). This study found that with the change in environments, children's attentional abilities increased and their hyperactivity symptoms decreased. Statistical analysis showed that 19% of the improvement in the children's attentional ability could be explained by the increase in their neighbourhood greenness. By comparison the improvement in housing quality explained only 4% of the improvement in attentional ability (Wells, 2000).

Berman, Jonides, and Kaplan (2008) conducted experiments on adult subjects that showed cognitive benefits from interacting with nature. These benefits were evident after both a walk in a green environment or just looking at pictures of natural settings. These researchers suggest that the cognitive benefits are derived from the restorative effects of greenspaces on attentional ability as described by Attention Restoration Theory (ART: Kaplan, 1995). Attention Restoration Theory is based on research that shows that the cognitive ability of attention is divided into an involuntary component, where attention is captured by inherently interesting or important stimuli, or directed attention, where attention is directed by conscious cognitive processes. Aside from requiring cognitive effort, directed attention involves resolving conflict when one needs to suppress distracting stimuli in order to maintain focus. This causes directed attention to deplete cognitive resources. According to ART, interacting with environments that are inherently fascinating invokes involuntary attention which allows for the replenishment of directed attentional resources (Kaplan, 1995). ART has also been used to explain the benefits of greenspace exposure on attentional capacities of children diagnosed with ADHD. A study surveying parents of children diagnosed with ADHD ( $N = 96$ ) which

investigated the effect of common activities on their child's ADHD symptoms showed that activities performed in greenspaces were consistently rated as 'best' for reducing ADHD symptoms. Furthermore this study showed that the 'greener' the child's everyday environment the more manageable their ADHD symptoms were overall (Faber-Taylor, Kuo, & Sullivan, 2001). A strength of this study is that it also compared outdoor activities in non-greenspaces to separately account for the variables of 'outdoor activity' and 'outdoor activity in greenspaces'. The analysis showed that activity in outdoor built environments was significantly less effective than activity in green environments and no better than indoor activities in reducing ADHD symptoms (Faber-Taylor et al., 2001).

Apart from its restorative effect on attentional capacities, greenspace exposure may promote cognitive development through increased creative play and socialisation. A study comparing patterns of children's play between 64 urban outdoor spaces in Chicago found that in outdoor spaces with lower levels of vegetation, children exhibited about half the level of play activity than in areas with higher ratings of greenness (Faber-Taylor, Wiley, Kuo, & Sullivan, 1998). Importantly, this study also analysed the type of play that children were engaged in and found that the level of greenness correlated strongly with an increase in more creative forms of play. This provides some evidence that exposure to greenspaces may encourage development of creative cognitive faculties. The importance of greenspaces as an environment for unstructured play may also contribute to its effect on children's cognitive development. In a survey of children's weekly activities researchers found that children who spent more time in less-structured activities had better levels of self-directed executive functioning (Barker et al., 2014). Conversely

children who had more structured activities in their weekly schedule showed poorer self-directed executive functioning.

## **1.5 Emotional Wellbeing**

Emotional wellbeing has been variously defined as a positive affective state “which enables an individual to be able to function in society and meet the demands of everyday life” (Mental Health Foundation, 2005) and as “being confident and positive and able to cope with the ups and downs of life” (Stewart-Brown, 1998). Research has shown that emotional wellbeing is an important contributing factor to desirable outcomes such as good mental health, high workplace engagement, and physical wellness (Shuck & Thomas, 2014; Nath & Pradhan, 2012; Valois, Zullig, Huebner, & Drane, 2004). Epidemiological research suggests a global prevalence of child and adolescent mental health disorders of 20% of which depression is the most frequently diagnosed (WHO Atlas, 2005). Because of the association between emotional wellbeing, mental health, and individual flourishing it is important to understand the factors that influence emotional wellbeing in children. This section will outline measurement of emotional wellbeing (Section 1.5.1); the associations between emotional wellbeing and physical activity (Section 1.5.2); and the associations between emotional wellbeing and greenspace exposure (Section 1.5.3). Several studies which have investigated the effect of ‘green exercise’ (physical activity within greenspaces) on emotional wellbeing will also be reviewed (Section 1.5.4).

**1.5.1 Measuring emotional wellbeing.** Subjective emotional wellbeing is a measure of an individual's cognitive and affective evaluations of their lives. Although there are no universally accepted definition of subjective emotional wellbeing it is generally defined as a construct which includes domains such as life satisfaction,

positive and negative affect, and happiness (Diener, 1984). Internationally, the last two decades have seen growing academic interest in the measurement of child well-being resulting in the development and validation of survey instruments to allow quantitative analysis of emotional wellness in children (Rees, Bradshaw, Goswami, & Keung, 2008). Two of these measures are outlined below.

***Huebners Life Satisfaction Scale.*** In a survey of 7000 children from the UK the Huebner's Life Satisfaction scale (Huebner, 1991) was found to be a stable measure of overall happiness. It also showed a high level of reliability, and factor analysis confirmed that it measured a single underlying construct (Rees, Goswami, & Bradshaw, 2010). Rees et al (2010) also found that it was possible to shorten the scale from seven items to five items with no substantial loss of reliability. The five items included in the scale are; 'My life is going well'; 'My life is just right'; 'I wish I had a different kind of life'; 'I have a good life'; and 'I have what I want in life'. Each item is rated on a five point scale from 'Strongly agree' (4) to 'Strongly disagree' (0). For scoring, the third item score is reversed, then all five scores are summed to give a life satisfaction score in the range 0-20.

***Ten Domain Index of Wellbeing (TDIW).*** Subjective wellbeing can also be thought of in relation to specific domains of life. A survey of 8,000 UK children run by the UK Children's Society in 2005 identified 12 life domains that children reported as being relevant to their wellbeing (Rees et al., 2008). Further factor analysis discovered that 10 of these 12 domains had a statistically significant independent effect on a child's overall happiness. These 10 domains are family, friends, health, appearance, time use, the future, home, money and possessions, school, and amount of choice. In the TDIW these 10 domains are each scored on a 0-10 scale which can

then be analysed independently or summed to give an overall 0-100 wellbeing score (Rees et al., 2010). The TDIW has been employed in the U.K. in national surveys of children's emotional wellbeing and shown good levels of reliability and stability (Rees et al., 2010).

**1.5.2 Children's emotional wellbeing and physical activity.** Although well-established associations between physical activity and emotional health have been found in adult populations (Penedo & Dahn, 2005), there is a paucity of research investigating this relationship in children. The literature that does exist in this area has largely used the presence or absence of diagnosed mental health disorders (e.g. depression or anxiety) as a proxy measure of children's emotional wellbeing. Observational studies on child and adolescent populations have generally reported small and insignificant, or modest associations between physical activity and depression (Janssen & Leblanc, 2010).

Experimental studies have consistently shown beneficial effects of exercise interventions on many psychological measures. One such study which was conducted in a low socioeconomic area of Santiago, Chile compared two classes of 15 year olds ( $n = 98$ ) who were selected to participate in a school based exercise programme with two control classes ( $n = 100$ ) who did not participate in the programme. The programme consisted of three supervised 90 minute exercise sessions per week. The students were tested for physical and mental health at the beginning of the study and after one year of the programme. At the end of the year the researchers found that the children enrolled in the exercise group showed significant decreases in anxiety scores (-13.7%) compared to the control group (-2.8%), ( $p < 0.01$ ). Participants in this study also showed an increase in self-esteem



scores (2.3%) compared to a small decrease in the control group (-0.1%), ( $p < 0.0001$ ). However no significant change was observed in the depression score for either group (Bonhauser et al., 2005). Another experimental study investigated the effects of a ten week exercise programme on adolescent mental health (Norris, Carroll, & Cochrane, 1992). This study randomly allocated students into either a high intensity aerobic exercise class, a moderate intensity aerobic exercise class, a flexibility class, or a control group. Each intervention group had two 25-30 minute classes per week over the 10 week study period. At the end of the study the high intensity exercise group had significantly lower scores for anxiety, depression, and hostility than the other three groups. Interestingly the moderate intensity exercise group showed no improvement in any physical or psychological measures suggesting that perhaps the relationship between emotional health and exercise is dose or intensity dependent (Norris et al., 1992). A further experimental study by Annessi (2005) investigated levels of depression and negative mood in 9-12 year old children who were enrolled in a 12 week after school exercise programme. A significant reduction in depression and total mood disturbance was found compared to a control group who did not participate in this programme. A review of this literature concluded that children's physical activity was consistently related to improvements in psychological measures of wellbeing. The pooled effect sizes were  $d = 0.12$  for self-esteem;  $d = -0.15$  for anxiety; and  $d = -0.38$  for depression (Calfas & Taylor, 1994). This review found inconclusive results for the relationship between hostility and physical activity. Another more recent systematic review and meta-analysis looking at the effect of physical activity interventions on child and adolescent depression also found a significant improvement in mental health following exercise interventions (Brown, Pearson, Braithwaite, Brown, & Biddle, 2013). This review included randomised controlled trials with a combined 581

participants, and found an overall effect of exercise interventions on depression that was small but statistically significant.

**1.5.3 Children's emotional wellbeing and greenspace exposure.** There is evidence from studies on adult populations that exposure to greenspaces have a positive effect on emotional wellbeing. In a study on university students, Zelenski and Nisbet (2014) found that an individual's self-reported connectedness to nature was significantly related to their self-reported level of happiness. This study also found that 'nature relatedness' exists as a separate construct from other forms of connectedness which indicates that perceived connection with nature has a distinct mediating effect on an individual's happiness. A small ( $N = 25$ ) exploratory study has found that individuals living in deprived communities with a greater quantity of greenspace in their living environment had significantly lower self-reported stress ( $p < 0.05$ ) and also lower salivary cortisol levels ( $p < 0.01$ ) than those living in similarly deprived neighbourhoods with less greenspace (Thompson et al., 2012). Salivary cortisol is a reliable marker for emotional and physiological stress levels (Hellhammer, Wüst, & Kudielka, 2009). In a quasi-experimental study, mental health scores in adults who had moved to neighbourhoods with higher 'greenness' ratings were compared with those who had moved to neighbourhoods with lower levels of 'greenness' (Alcock, White, Wheeler, Fleming, & Depledge, 2014). This study followed the participants for three years and found long term effects of increased neighbourhood greenness. Participants who moved to greener localities had significantly better mental health scores in all three years of follow up. Those who moved to less green neighbourhoods had a decrease in mental health score at one year post-move followed by a return to baseline levels in the next two years (Alcock et al., 2014). Although the analysis adjusted for several possible confounds, the study did not measure participant's

physical activity levels before or after their change in neighbourhood and so is unable to account for this as a possible mediating effect.

The evidence linking greenspace exposure and emotional wellbeing in children is somewhat contradictory. Wells and Evans (2003) conducted a study on 337 rural children from the UK. They measured parents and children's ratings of psychological distress and self-worth and compared them to ratings of greenness around the children's residence. This study found that those with more nature around their home environment showed lower ratings of emotional distress (behavioural conduct disorders, depression, and anxiety). This study also suggests that nature around the home environment buffered the negative psychological effects of stressful life events on children (Wells & Evans, 2003). A limitation of this study is that they did not investigate children's activity levels. As detailed above, children with greater exposure to greenspaces are likely to engage in higher levels of physical activity so whether the observed improvement in emotional wellbeing is independent of differing physical activity levels cannot be determined from this research. This study also only considered rural children, so its results may not generalise to children in more urban localities. In contrast to this finding, a large cross-sectional study of Canadian children found only weak and inconsistent relationships between neighbourhood greenspace and positive emotional wellbeing (Huynh, Craig, Janssen, & Pickett, 2013). A strength of this study was that it used a large sample ( $N = 17,249$ ) of children from across Canada. However a weakness is that the measure of greenspace exposure used was the percentage of public natural spaces in a 5km radius around the child's school. This measure does not necessarily include the child's home environment and is not sensitive to individual variations in use of, and exposure to, the greenspaces in their neighbourhood (Huynh et al., 2013).

One factor that may partially mediate the relationship between greenspace exposure and emotional wellbeing in school age children is the presence of ‘bullying’ during school play times. In a survey of Australian primary schools it was found that school grounds that contained higher levels of vegetation and lower levels of crowding in the playground had significantly fewer reported incidences of bullying (Malone & Tranter, 2003). It is also plausible that outdoor activity would confer benefit to children’s mood due to increased exposure to sunlight and the resultant effects on melatonin and cortisol levels in the brain (Wirz-Justice et al., 1996).

**1.5.4 Combined effects of physical activity and greenspace exposure on emotional wellbeing.** There is a small body of research that has looked at the effect of green exercise which involves physical activity in natural environments. Green exercise has been shown to have a positive effect on emotional wellbeing. For example, Hartig, Evans, Jamner, Davis, and Garling (2003) found that adult subjects who engaged in a 50 minute walk in a natural environment showed increased positive affect and decreased hostility compared to those who completed a 50 minute walk in an urban setting. To test the differential effects of physical activity and surroundings on emotional wellbeing, a 2005 study was conducted involving volunteers who were exposed to different rural and urban scenes while running on a treadmill (Pretty, Peacock, Sellens, & Griffin, 2005). This study found a significant effect of exercise on both self-esteem and mood, with a greater benefit when the runners were exposed to pleasant rural and urban scenes. Both rural and urban scenes that were rated as ‘unpleasant’ had a deleterious effect on both self-esteem and mood. This study supports the idea that exercise in a pleasant environment has benefits on emotional wellbeing but it did not show a specific benefit for ‘greenness’ of the pleasant scene.

It is unknown however to what extent running on a treadmill while looking at a picture replicates the true experience of running in a natural environment (Pretty et al., 2005).

Barton and Pretty (2010) conducted a meta-analysis on the effect of green exercise on mood and self-esteem. This review included 10 studies involving a total of 1,252 adult participants. The overall effect size of green exercise on self-esteem was  $d = 0.46$  ( $p < 0.00001$ ) and on mood was  $d = 0.54$  ( $p < 0.00001$ ). The effect of both exercise intensity and duration of greenspace exposure showed a non-linear dose-response relationship, with large benefits from small engagements and diminishing additional benefits from longer engagements. This analysis did not include studies with measures which would allow separate consideration of the effect of the physical activity and the effect of the greenspace exposure on wellbeing. Also all the research in this area has been conducted on adult populations, whether similar associations would be found in children is currently unknown.

## **1.6. Risk-taking**

Risk-taking is defined as “the practice of taking action which might have undesirable consequences” (Collins Dictionary, n.d.). Risk-taking is of interest in health research as it is well recognised that some behaviours have potentially negative health consequences (e.g. smoking, seatbelt non-use, illicit drug use). Therefore individual, social, or environmental factors that influence the likelihood of someone engaging in these behaviours can be significant mediators of health outcomes (Wills, Vaccaro, & McNamara, 1994). This section will briefly review the literature on the measurement of risk-taking in health research (Section 1.6.1); the small amount of research that has investigated associations between risk-taking and

physical activity in children will be outlined (Section 1.6.2); and the literature linking risk-taking propensity to greenspace exposure will also be reviewed (Section 1.6.3).

**1.6.1 Measuring risk-taking behaviour.** The assessment of risk-taking has mostly relied on self-report measures of impulsivity, sensation-seeking, and venturesomeness. The validity of such self-report measures has been called into question due to bias arising from participant's perceived negative consequences of reporting risky behaviour and potential lack of insight into their risk-taking (Lejuez et al., 2002). In response to these shortcomings, Lejuez et al (2002) developed the Balloon Analogue Risk Task (BART) and the Balloon Analogue Risk Task- Youth version (BART-Y). These are behavioural measures of risk-taking, which have been designed to reflect some elements of risk-taking present in the natural environment.

***Balloon Analogue Risk Task (BART).*** The Balloon Analogue Risk Task is a computer-based measure that assesses risk-taking behaviour. The assessment involves participants pressing a computer key which inflates a balloon image on the computer screen. Each pump of the balloon earns the participants money in a temporary bank account. The participant continues to inflate the balloon until either the simulated balloon 'bursts', in which case they forfeit all the money in their temporary account, or they choose to stop pumping at any point and transfer the accumulated money into a permanent bank account. Each participant has a set number of balloons to inflate. The task has been developed to model risk-taking in the real world where a certain level of risk-taking can lead to positive outcomes but excessive risk-taking can lead to negative consequences (Lejuez et al., 2002). The youth version of the BART (the BART-Y) is identical to the adult version except rather than earning money for inflating the balloons the BART-Y uses 'points' as a reward (Lejuez et al., 2007). In a

study of 98 American high-school students the BART-Y scores showed an association with established measures of risk-related personality constructs such as impulsivity and sensation-seeking. This study also found BART-Y scores were related to adolescent's self-reported risk-taking behaviours including substance abuse, sexual behaviour, and delinquency (Lejuez et al., 2007).

*Short form Sensation-seeking Scale (SFSSS).* Sensation-seeking is a personality trait characterized by the need for varied, novel, and complex sensations and experiences, and the willingness to take physical and social risks for the sake of such experiences (Zuckerman, 1990). Sensation-seeking is associated with risk-taking behaviour (Horvath & Zuckerman, 1993) and may exist as a mediating variable between risk-taking, physical activity, and greenspace exposure (Wilkinson et al., 2013). Sensation-seeking is most commonly assessed with Form V of the Sensation-seeking Scale (SSS-V; Zuckerman, Eysenck, & Eysenck, 1978). This is a 40 item questionnaire which comprises four subscales for disinhibition, experience seeking, boredom susceptibility, and thrill seeking. In order to find a shorter research tool that would be more acceptable for widespread use researchers have developed the Short Form Sensation-seeking Scale (SFSSS) (Stephenson, Hoyle, Palmgreen, & Slater, 2003). This scale consists of four items which correspond to the four subscales of the SSS-V. In research on 5,000 children aged 11-15 scores on the SFSSS were found to correlate extremely well with the results of the 40 item scale. This study also found that SFSS scores were suitably correlated with established risk-taking behaviours such as alcohol, tobacco, and marijuana use (Stephenson et al., 2003).

**1.6.2 Children's risk-taking behaviour and physical activity.** A small amount of research with adults has shown a positive association between engagement in regular physical activity and some behavioural markers of risk-taking such as seatbelt use and good driving habits (Blair, Jacobs & Powell, 1985). These authors conclude that traits such as lower risk-taking and greater exercise involvement may be associated with a general orientation of health protection or promotion (Blair et al., 1985).

There is a paucity of research investigating the link between physical activity and risk-taking in children. One study that has investigated this relationship used data from 11,957 subjects enrolled in the National Longitudinal Study of Adolescent Health. The researchers compared self-reported levels of active and sedentary behaviour with self-reported levels of high risk behaviours. This study showed that participation in a large range of sporting activities, especially ones which included parental involvement, was associated with lower levels of high risk behaviours. The authors concluded that enhancing opportunities for sport involvement and general physical activity may have a beneficial effect on adolescent risk behaviours (Nelson & Gordan-Larsen, 2006). An earlier survey of American school children likewise found associations between increased levels of physical activity and lower engagement in risky health-related behaviours such as illicit drug use, cigarette and alcohol use, early sexual activity, and non-use of seatbelts (Pate, Heath, Dowda, & Trost, 1996). This study was also limited by its reliance on self-report data.

**1.6.3 Children's risk-taking behaviour and greenspace exposure.** Barker (2004) proposed that children who have experienced appropriate levels of risk are



more likely to develop responsible attitudes toward danger. Such appropriate risk-taking also introduces excitement and extends the skill of children and has been positively correlated with creativity and self-confidence (Goodyear-Smith & Laidlaw, 1999). Conversely, it is believed that insufficiently challenging play activity can lead to inappropriate risk-taking as children seek excitement without sufficient caution (Greenfield, 2003). Greenspaces have been identified as providing ideal venues for outdoor unstructured play and can therefore provide many opportunities for such risk-taking (Fjortoft & Sageie, 2000; Louv 2005). Much of the literature describing the relationship between greenspace exposure and children's risk-taking behaviour is theory driven. There is no observational or experimental research that has examined this association.

Any potential association between greenspace exposure and risk-taking behaviour could be mediated by the personality trait of sensation-seeking. Research has shown that in university students increasing levels of sensation-seeking are strongly predictive of risk-taking behaviour (Horvath & Zuckerman, 1993). Given the propensity for individuals with strong sensation-seeking tendencies to seek out novel and intense experiences it is possible that a sensation-seeking trait is also independently associated with increased time spent in greenspaces. It would be important for any research into this relationship to be able to adjust for this potential confound.

## **1.7 Conclusion**

Increased MVPA in children is associated with many physical, cognitive, and emotional health benefits over an individual's life course as well as national level economic benefits such as greater worker productivity and reduced use of health care

services. However, research shows that many young people in New Zealand do not meet recommended levels of physical activity. In light of this there is a need for research to identify the environmental, social, and individual variables that affect children's level of engagement in physical activity. The neighbourhood environment has been identified as a key environmental exposure for children and research has investigated many variables within the neighbourhood as potentially associated with physical activity. Greenspaces provide a suitable environment for children to engage in MVPA, and a growing body of research shows that the amount of time children spend in greenspace is positively correlated with their physical activity levels. There is also preliminary evidence that exposure to greenspaces has a beneficial effect on children's cognitive development and level of emotional wellbeing as well as a postulated link with children's ability to appraise risk.

The literature investigating these relationships is weakened by the use of indirect measures of greenspace exposure and a reliance on subjective measures of physical activity. However, more recently, research into the health benefits of greenspace exposure and physical activity has been greatly aided by advances in technology that allow detailed, objective, individual locational and activity information to be recorded and analysed using quantitative statistical methods. There is a need for further research to take advantage of these measurement and methodological advances in order to better understand the relationships between children's interactions with their neighbourhood environment, their exposure to greenspaces, their engagement in physical activity, and their overall health and wellbeing.

## **Chapter 2: Introduction**

### **2.1 The need for the current research**

Questions regarding the role of exposure to natural environments in healthy childhood development are increasingly important. As outlined in the previous chapter, there is evidence that children's exposure to greenspace is associated with increased physical activity levels. Also, both greenspace exposure and physical activity have in turn been associated with physical, cognitive, emotional, and behavioural variables relevant to children's healthy development. However, despite these beneficial associations, there is evidence that children's exposure to both their wider neighbourhood and to greenspaces is decreasing due to factors such as increased urbanisation and cultural changes in parenting beliefs and behaviours (Fyhri et al., 2011; Juster et al., 2004). The following section will highlight some of the shortcomings in the existing body of literature which will be addressed in the current research.

**2.1.1 Improvements to measurement of variables.** A key weakness of much of the previous research in this area is the dependence on subjective, self-report measures of physical activity and greenspace exposure. There is evidence that such subjective measures provide less accurate data on physical activity behaviour than objective measurement, particularly in children (Prince et al., 2008; Telford, Salmon, Jolley, & Crawford, 2004). Also, many of the objective measures that have been used to quantify greenspace exposure – such as distance to the nearest greenspace or the number of greenspaces in the neighbourhood – are in fact proxy measures of greenspace exposure, and the extent to which these measures correlate with the amount of time an individual actually spends in greenspace is unknown. There is a need for more research that uses newly developed technologies, such as accelerometry, GPS, and GIS, to

provide objective, accurate, and detailed information on children's physical activity and location patterns.

The existing literature also uses a variety of measures of cognition, emotional wellbeing, and risk-taking. Some of these measures are open to bias, such as the use of parental reports for measuring child wellbeing. Other measures are indirect, such as the use of academic test scores as a surrogate measure for cognitive development. With the development of simple, validated, and objective measurement tools, such as CNS-VS (Gualtieri & Johnson, 2006), the BART-Y (Lejuez et al., 2007), and validated subjective measures such as the 10 Domain Index of Wellbeing (TDIW; Rees et al., 2010), it is possible for future research to glean more valid and reliable data on these variables.

**2.1.2. A need for more research in this field specifically on children.** As outlined in Chapter 1, concerns about the declining health standards of young people in many developed countries have led to increased awareness of the importance of health promotion in children (Ministry of Health, 2013; Salmon et al., 2005; Turnbull et al., 2004). This requires development of a robust, empirically-supported knowledge framework regarding the factors that influence healthy childhood development. Currently, much of the research investigating links between neighbourhood variables, greenspace exposure, and physical health behaviours has been conducted on adults, with relatively little known about the associations between these variables in child populations. There is evidence that the use of recently developed technologies, such as GPS and accelerometry, is viable in child and adolescent populations (Hinkson et al., 2014; Oliver et al., 2011), and so there is a need to use these methods to specifically

investigate the connections between children's environmental exposures and physical health.

**2.1.3 Investigation of the association between children's risk-taking behaviour and greenspace exposure and physical activity.** In the literature reviewed the variable which has received the least amount of research attention is that of risk-taking behaviour. Earlier research has linked increased physical activity in adolescents with lower engagement in high-risk health behaviours such as smoking, illicit drug use, and early sexual activity (Nelson & Gordon-Larsen, 2006). However, this research is limited by its reliance on self-report data and its failure to account for potentially mediating variables: such as the 'sensation-seeking' personality trait, and levels of parental involvement in children's activities. Furthermore, although theorists have proposed links between time spent in unstructured play in natural environments and the development of healthy appraisals of risk (Greenfield, 2003), there is a lack of empirical research to either support or refute this claim. Research that uses validated measures of risk-taking, sensation-seeking, physical activity, and greenspace exposure is needed to investigate the strength of these associations.

**2.1.4 Investigation of the role of time in the neighbourhood environment on physical activity.** A large body of literature has developed over the past few decades investigating many variables within the neighbourhood as potentially associated with children's physical activity. As outlined in Section 1.3.3, this research has been largely inconclusive. Other streams of research have found evidence that children are spending less time interacting with their wider neighbourhood environment than previous generations (Bhosale et al., In Press). What is unknown is whether the neighbourhood environment as an exposure in its own right is positively or negatively associated with

physical activity. A study investigating the time participants spend in their neighbourhood environment and how that relates to individual outcomes such as physical activity would provide valuable information that could inform future research in this field. For instance, if time in the neighbourhood environment is positively associated with children's MVPA, then perhaps interventions aimed at increasing children's neighbourhood exposure could be planned as ways to encourage increased physical activity. Conversely, if time in the neighbourhood is not associated with children's MVPA then such interventions, by themselves, are likely to be ineffective.

**2.1.5 Differentiation between the effects of greenspace exposure and physical activity on emotional wellbeing, cognitive development, and risk-taking behaviour.** The literature reviewed in Chapter 1 includes several studies that have found positive associations between greenspace exposure and cognitive development or emotional wellbeing. Other research has also found that time in greenspace is associated with increased physical activity in children. These results leave open the possibility that physical activity acts as a mediating variable between greenspace exposure and cognitive performance or emotional health. In order to isolate their relative strengths of association, a study is needed which can objectively measure both greenspace exposure and physical activity and construct a statistical model where the relative effects of each variable can be independently controlled for.

It is possible that a large proportion of the reported cognitive and emotional benefits associated with greenspace exposure comes from the increased MVPA associated with time in these environments. In this case, a study that could differentiate between the effects of greenspace exposure and physical activity would expect to find associations between cognitive and emotional wellbeing measures and physical

activity, and also find a lesser or null relationship between these measures and greenspace exposure. Conversely, it is also possible that exposure to greenspaces is associated with cognition and emotional wellbeing independent of engagement in physical activity. Again, an appropriately designed study would be able to investigate these relationships. This knowledge would give a more detailed understanding of some of the underlying factors which contribute to healthy childhood development which could then have implications for the design of interventions to foster children's cognitive and emotional thriving.

## **2.2 Aims and research questions.**

The current research aims to investigate the associations between greenspace exposure and time spent in the neighbourhood environment with the physical activity of children. The associations between these variables and measures of children's cognitive development, emotional wellbeing, and risk-taking behaviour will also be explored. Thus this study has three key research questions:

1. Is children's exposure to greenspace associated with their physical activity levels?
2. Are children's greenspace exposure and physical activity levels independently associated with cognition, emotional wellbeing, and risk-taking behaviour?
3. Is the time children spend in their neighbourhood environment associated with their physical activity levels?

Questions 1 and 2 are addressed in the paper which comprises chapter 4 of this Thesis. Question 3 is investigated in a second paper which comprises chapter 5. The

methodology employed in this research, which is outlined in Chapter 3, was designed in view of the gaps in the existing body of knowledge.



## **Chapter 3: Method**

### **3.1 Participants**

Prior to commencing the recruitment phase of the study, a power analysis was conducted to ascertain the required sample size. The G\*Power 3.1.7 application (Faul, Erdfelder, Buchner, & Lang, 2009) was used for this calculation using the assumptions  $\alpha = 0.05$ , power = 0.80. This found that in order to detect a moderate correlation ( $r = 0.30$ ) between exposure to greenspace and any of the outcome variables, a sample size of 84 participants was required. To allow for ~15% loss of data through non-compliance or equipment failure the current study aimed to recruit 100 participants.

The process of recruiting participants began by approaching intermediate schools in the Auckland region to invite them to participate in this research project. This commenced in June 2014 with schools being contacted by phone, and if they expressed interest in the project, a follow-up email with more detail being sent. Also at this point a letter explaining the purposes, procedures, and ethical considerations of the study was sent to the Board of Trustees at interested schools. A copy of this letter has been included in Appendix 1. At two of the schools, face to face meetings were also held with the principal or senior management to discuss details and address concerns that they had raised. Schools were approached based on two main criteria. Firstly, schools were selected to cover geographically, culturally, and socioeconomically diverse neighbourhoods. Secondly, practical matters such as existing relationships with the school and geographic proximity to the researcher's home, were considered in which schools to approach. In total nine schools were contacted and three of them agreed to participate. These schools will be identified as school 1, 2, and 3 throughout the rest of this document.

The next stage of recruitment involved sending information sheets with student assent and parental consent forms home with students. Copies of these documents have

been included in Appendix 2. These were distributed by the school to all students in years 7 and 8 (ages 10 to 14). In total these information packs were sent out to 590 students in the 3 participating schools. Of these, 126 signed consent and assent forms were returned; a response rate of 21.4%.

### **3.2 Informed Consent and Ethical Considerations**

The information pack explained the purpose and nature of the research. It also outlined what would be required of students who opted to participate in the research, how their privacy and autonomy would be respected, and provided contact information for any parent/caregiver who wanted to ask further questions. Consent forms explained that participation in the study was purely voluntary, assured the parents that their child's confidentiality would be respected at all times, and informed them that they would be able to withdraw from the study at any time for any reason. Assent forms outlined the same information with slight differences in wording to make it more understandable for the participants. The forms also explained that the proposed study had been approved by Auckland University of Technology's Ethics Committee. All participants were given the opportunity to receive a report of the study results at the end of the project.

Because the study involved the collection of potentially identifying data such as locational information, participants were assured that no data that made it possible for them to be identified would be disclosed or included in any publications. All participants were given a code which was then used as the identifier for all their data collected in both paper and electronic formats. Data security measures included all electronic data collected being stored on a password protected hard drive, and all information gathered as a hard copy being stored in a locked filing cabinet on AUT

premises. This data will be stored for 10 years and then destroyed. Approval for this study was granted by the Auckland University of Technology Ethics Committee on 12<sup>th</sup> May, 2014 (AUTEC Reference number 14/61).

### **3.3 Procedures**

Data collection took place between September and December 2014. At each of the schools the data collection period ran for seven days commencing on a Monday and concluding the following Monday. On the first day of data collection at each school, students were called out of class in small groups to receive their instructions, complete the initial testing, and be fitted with the GPS and accelerometer devices. All the participating schools made suitable space available for the researchers to work in, and also provided access to either school laptops or the school computer lab for the computerised part of the testing. Greater detail on the specific measures utilised is provided in Section 3.4.

Each participant received a pack labelled with their coded identification number which contained their belt, devices, activity log, non-wear diary, and a written copy of the device use instructions. They were then separated by gender for physical measurements which were taken by a gender-matched researcher. After these measurements were recorded, the participants were given the Activity and Wellbeing questionnaire to fill out (see Appendix 3). Once this was completed they were fitted with their belts and devices and given verbal instructions outlining the wearing, charging, and care of the devices. The researcher also showed them the activity log and non-wear diary that they were asked to fill in on a daily basis. These contained an example section that was pre-filled to demonstrate the level of detail that was expected. Participants were given opportunities to ask questions throughout this instruction and

the information sheets included the researcher's contact details in case participants or their parents had any questions or concerns during the week.

Once participants were fitted with their devices and had received these instructions they underwent the computerised cognitive testing and risk-taking assessment. They first completed the CNS Vital Signs test battery (CNS-VS) and then the Balloon Analogue Risk Task (BART-Y). Research assistants aided the students in accessing these web-based applications and giving supplementary instructions to ensure that they were performing the tests properly. Both CNS-VS and BART-Y have been specifically designed for use by this age group and therefore have simple user-interfaces and instructions. In practice, many students needed to be coached in both accessing and performing the testing. Once students completed this testing they resumed their school day. Total testing for each batch of participants took approximately 70-90 minutes. At each of the schools there was some degree of participant loss due to student absence. These levels of absence were; 4 out of 54 at School 1; 1 out of 31 at School 2; and 3 out of 41 at School 3. Due to restrictions in access to the schools and their resources, testing of these participants on another day was not possible. Therefore, of the 126 students who consented for the study, 118 participated in the data collection.

The following Monday the study packs containing the belts, devices, activity logs, and non-wear diaries were collected from the students. At this point the intent was to utilise a web-based interactive mapping tool (The Visualization and Evaluation of Route Itineraries, Travel destinations and Activity Spaces survey: VERITAS) as a measure of chronic environmental exposures which could augment the GPS data collected. However, a working version of this survey was not available in time for data

collection. In lieu of this the researcher and assistants briefly reviewed the participant's activity logs with them using Google Maps™ as a resource for finding locations and street addresses they had reported spending time in. This prompted participant's recall of their weekly activity and where necessary facilitated them recording more complete data in their activity logs. This directed review of the activity logs took 5-15 minutes for each participant.

### **3.4 Measures**

**3.4.1 Global Positioning System (GPS) receivers.** Objective geolocational information was gathered using the Qstarz BT-Q1000XT GPS receiver with MTK II chipsets (Qstarz International, Taipei, Taiwan). These devices have exhibited relatively high accuracy under various environmental conditions; data capacity of 400,000 waypoints; a reported signal acquisition time of 35 seconds from cold start; and an observed battery life of 39.8 hours (Duncan et al., 2013). These devices have been used in previous research of this type and their accuracy and suitability has been established (Schipperijn et al., 2014). This receiver was worn on a supplied waist belt during the seven day monitoring period and configured to record data every 15 seconds. Participants were instructed to wear the device at all times unless bathing, swimming, or sleeping. Due to the limited availability of these devices not all participants were fitted with them. GPS devices were distributed to the first 26 students measured at each school along with accelerometer devices, after which remaining participants were only fitted with accelerometers. Over the three schools investigated, 78 students were fitted with GPS devices. They were given verbal and written instructions regarding use of the device and a diary to record non-wear time. A charger was given to each student along with instructions for them to charge the device overnight, every night of the study. Although the battery life of these devices did not

necessitate such frequent recharging, nightly charging was chosen as a convenient routine which could also act as a prompt for the participants to complete their daily activity diaries. The written instructions and wear-time diary that each participant received are included in Appendix 4.

**3.4.2 Accelerometry.** Physical activity frequency, duration, and intensity were measured using the Actigraph GT3X+ accelerometer (Actigraph, <http://www.actigraphcorp.com>, Pensacola, FL). The GT3X+ monitor is a small (3.8×3.7×1.8 cm), lightweight (27 gm), and robust tri-axial physical activity monitor (Actigraph, 2012). These devices were configured to collect data in 10 second epochs at a 30Hz sampling rate. The GT3X+ accelerometer also has a low-frequency extension option which allows increased sensitivity to low-intensity activities. This option was turned off for the current study as it was primarily interested in measuring physical activity in the moderate to vigorous range. These devices have a reported battery life of 30 days which meant that recharging was not necessary over the seven day monitoring period (Actigraph, 2012). The accuracy and validity of these devices for use on child populations has been established against both indirect calorimetry and other accelerometer devices (Evenson et al., 2008; Trost et al., 2011). These devices were also worn on the supplied belt over the right iliac crest as per previous research (Evenson et al., 2008; Treuth et al., 2004). The count thresholds used to distinguish between varying activity levels were; sedentary < 101 counts per minute (CPM); light = 101-2295 CPM; moderate = 2296-4011 CPM; and vigorous > 4011 CPM. These cut points have been validated for use on children by previous research (Evenson et al., 2008). Verbal and written instruction on correct use of the device was given similar to the GPS receiver (see Appendix 4). Between the three schools involved in the study 118 students were fitted with accelerometers.

**3.4.3 Physical measures.** The standing height of each participant was measured to the nearest millimetre with a portable stadiometer (Design No. 1013522, Surgical and Medical Products, Seven Hills, Australia), and weight was measured to the nearest 0.1 kg on a digital scale (Model Seca 770, Seca, Hamburg, Germany). BMI was then calculated as weight (kg) divided by squared height (m<sup>2</sup>). In addition, waist circumference measurements were made at the highest point of the iliac crest at minimal respiration, and the waist to height ratio was calculated. All measurements on students were made by a gender-matched researcher and appropriate steps were taken to ensure the privacy of participant's physical measurements.

**3.4.4 Neurocognitive testing.** Computerised neurocognitive testing was conducted using CNS Vital Signs (CNS-VS, [www.cnsvs.com](http://www.cnsvs.com)), a web-based battery of seven tests that are frequently used in neuropsychological analysis. The results of the CNS-VS test battery have been shown to correlate highly with conventionally administered neurocognitive testing and also show good levels of test-retest reliability in participants aged from 7-90 (Gaultiere & Johnson, 2006). In order to access these tests students had to log into the CNS-VS testing website ([www.cnsvsonline.com](http://www.cnsvsonline.com)) and enter their participant code. Written instructions for each of the tests were given and participants had a chance to practice each task to ensure their comprehension before being tested on it. Researchers were available to assist each student log in to the site and when necessary help explain the test procedures to students. Testing proceeded slightly differently at each school. At School 1 the researchers were given access to laptop computers in the library and students were seated around tables in a corner of the library. At School 2 and School 3 the computerised testing was completed in the school's computer laboratory where workstations were located around the walls of the

room. These differences may have affected the student's performance as the library at School 1 was a much busier environment than the computer labs, and having students facing inwards at a table led to noticeably more distracted behaviour than when the computers were against the walls and thus the students were facing away from each other. CNS-VS calculates the subject's performance in the following cognitive domains; visual memory, verbal memory, processing speed, psychomotor speed, reaction time, cognitive flexibility, and executive function. Results for each domain are given in terms of participant's raw score, a standardised score which is adjusted for their age, and their percentile attainment compared to results of a database of age-matched, cognitively normal subjects.

**3.4.5 Risk-taking.** Risk-taking behaviour was assessed using the youth version of the Balloon Analogue Risk Task (BART-Y; Lejeuz et al., 2007), a computer-based behavioural measure designed to reflect some elements of risk-taking present in the natural environment. Participants logged in to a website and downloaded a Java file which launched the test application. The test itself involves inflating a series of virtual balloons. As the balloons are progressively inflated the participant earns more points, however the probability of the balloon bursting also increases as it inflates. If the balloon bursts the student loses all their points. At any stage participants can stop inflating the balloon at which time their point total for that balloon is saved and added to their overall total. Participants were given 30 virtual balloons to inflate. At the end of testing they accrued a total score determined by the size and number of un-popped balloons they accumulate. From a risk-taking viewpoint the key outcome is the average size of the participant's un-popped balloons. Participants who are greater risk-takers are more likely to 'push the limits' by inflating the balloons more before saving the points. Conversely, risk averse participants will opt for the safety of saving the points



before the balloon gets too large. In strict administration of the BART-Y various prizes are offered as incentives for students getting larger scores. Due to restrictions in the research budget the current study was unable to offer such rewards, but participants were encouraged to do their best and competition between students to get the highest score was encouraged. The BART-Y has been shown to correlate with real world risk-taking behaviours such as substance abuse, early sexual behaviour, and delinquency in adolescents (Lejuez et al., 2002, Lejuez et al., 2007). Using a behavioural measure of risk-taking avoids the potential limitations of self-report measures which may arise from both the perceived negative consequences of reporting risky behaviour and also a possible lack of insight into their own risk-taking (Lejeuz et al., 2002).

#### **3.4.6 Activity and Wellbeing questionnaire.**

***Emotional Wellbeing.*** Wellbeing was assessed with three different self-report measures. The Life Satisfaction Scale (LSS) is a 5-item questionnaire derived from Hubener's Student Life Satisfaction Scale (Huebner, 1991). Participants also completed the TDIW which asks the participant to rate their happiness in ten different life domains on a scale from 0 to 10, which are then summed to give an aggregate wellbeing score between 0 and 100 (Rees, Goswami & Bradshaw, 2010). Lastly a single item measure of "happiness with life as a whole" (HS) measured on a scale from 0 to 10 was included. These three scales have been validated for use in national surveys of children's emotional wellbeing in England and all have been shown to exhibit good levels of reliability and stability (Rees, Goswami & Bradshaw, 2010).

***Sensation-seeking.*** Sensation-seeking is a personality trait characterised by the need for varied, novel, and complex sensations and experiences, and the willingness

to take physical and social risks for such experiences (Zuckerman, 1990). This was measured using the Short Form Sensation-seeking Scale (SFSSS: Stephenson et al., 2003). This scale consists of four items which relate to the four domains of sensation-seeking (disinhibition, experience-seeking, boredom susceptibility, and thrill-seeking). In research with 5000 children aged 11-15, scores on the SFSSS were found to correlate well with the results of a more comprehensive and well validated 40-item scale (Stephenson et al., 2003; Zuckerman et al., 1978). SFSSS scores have also been shown to correlate well with established risk-taking behaviours- such as tobacco, alcohol, and illicit drug use- in teens and pre-teen children (Stephenson et al., 2003).

**3.4.7 Activity diary.** All participants were given an Activity diary to complete during the week (see Appendix 5). They were instructed to fill out this diary with each location they visited each day, the physical address of this location, and their method of travel to that location. To aid in accuracy of recall they were asked to fill it out each day at the end of the day. Upon collection of the devices they reviewed their completed diary with the researcher or an assistant. Any incomplete information could then be filled in. To assist this process the participant and researcher used the Google™ search engine and Google Maps™ website in order to identify locations and addresses that had not been completely filled in. This brief supervised review helped to ensure completeness and accuracy of the collected data.

### **3.5 Data processing**

Immediately after device collection the GPS and accelerometer data were uploaded from the devices onto a password protected hard drive. Questionnaire data were entered into an excel spreadsheet for analysis. Data analysis took place during October 2014 to May 2015. GPS data and accelerometer data were merged using the

Personal Activity Location Measurement System (PALMS). This is a web-based application designed by the University of California, San Diego, which allows cleaning and processing of geolocational and accelerometer information and which merges the data files by coding each GPS waypoint with the intensity of movement at that particular location (Kerr, Duncan, & Schipperjin, 2011). The PALMS application aggregated and processed the accelerometer data into 15 second epochs. As described in Section 3.4.2 the Evenson (2008) cut points were used to classify different levels of activity for this study. Continuous periods of greater than 60 min of zero activity counts were classified as non-wear time and removed from the analysis (Corder, Ekelund, Steele, Wareham, & Brage, 2008; Troiano et al., 2008). The PALMS software also cleans and processes the GPS data by removing data points with unrealistic measures of speed or extreme changes in distance and elevation (Klinker, Schipperijn, Kerr, Ersbøll, & Troelsen, 2014). The PALMS application has been previously used as a data-processing tool by other studies investigating children's day-to-day physical activity and transport (Klinker et al., 2014)

**3.5.1 Data exclusion criteria.** For the 78 participants in which both GPS and accelerometer data had been collected, the two data sets were merged using PALMS software (as described above). The inclusion criterion for the merged GPS-accelerometer data was that each participant had at least three days of data collected with a minimum of four hours of valid data on each day. These criteria have been used in previous research of a similar nature (Almanza et al., 2012). This resulted in exclusion of six files from the analysis, leaving 72 combined activity and location files; an inclusion rate of 92%. There were also a further 40 accelerometer files without matching GPS data. These accelerometer files were included in the analysis provided that at least 10 hours of data had been gathered per day for a minimum of five days of

the monitoring period. These inclusion criteria were adopted from previous research into children's physical activity (Oliver et al., 2011). Of the 40 unmatched files, 36 met this criteria. This gave us a total dataset of 108 accelerometer files and 72 merged GPS and accelerometer files. The overall inclusion rate was 91.5%.

**3.5.2 Geographic information system (GIS) data processing.** The merged data streams retrieved from PALMS were imported into GIS for spatial analysis using ArcGIS software. (ESRI ArcMap 10.2.1). These data files were converted into shape files and analysed in three stages as outlined below.

(a) Greenspace. Greenspace information was taken from the 'Parks' dataset available through Open Street Map ([www.openstreetmap.org](http://www.openstreetmap.org)). This allowed the identification of time points located within greenspaces. The percentage of total data points inside greenspaces for each participant was calculated and these were separated for analysis. This dataset identified publically accessible parks, sports fields, and reserves. However, it did not contain information on other land areas that would also be categorised as greenspace such as accessible vacant land, private gardens, or school playgrounds. This dataset was chosen due to a lack of a more comprehensive resource covering the Auckland region.

(b) Neighbourhood. Participant's primary home address was entered into Google Maps <sup>TM</sup> to identify the coordinates of this location. These coordinates were plotted in ArcGIS and an 800m buffer created around this home point. This neighbourhood buffer was then joined to the individual's merged GPS-Accelerometer file to allow separation of in-neighbourhood and out-of-neighbourhood data points. Subjects were separated into quartiles for

analysis on the basis of the percentage of their total monitored time that they spent within the neighbourhood buffer.

(c) School. School boundaries were visually identified and mapped on ArcGIS and data points within these boundaries were also separated for analysis.

### **3.6 Statistical Analysis**

Each of the two papers written as part of this thesis required different statistical analysis. A brief summary of the statistical analyses follows. These are more fully outlined in the respective chapters (Sections 4.2.4 and 5.2.4). All statistical analyses were conducted using SPSS software (SPSS version 22).

**3.6.1 Greenspace and physical activity analysis.** Generalised linear mixed models (GLMM) were used to quantify the relationships between the percentage time in greenspace or percentage time in MVPA and the other measured variables. A GLMM allowed us to account for variations in the data from both fixed and random effects. All models specified child nested within school as a random effect.

**3.6.2 Neighbourhood analysis.** Generalised linear models were used to investigate the association between the quartiles of time in neighbourhood and each of the other variables. Initially these models were adjusted for participant's age and sex, but these factors were found to be non-significant and so were removed from the final analysis.

## **Chapter 4. Paper one- The impact of children's exposure to greenspace on physical activity, cognitive development, emotional wellbeing, and ability to appraise risk.**

### **4.1 Introduction**

Physical inactivity in children has been identified as a significant and growing public health concern (WHO Atlas, 2005). Regular MVPA in children is associated with numerous benefits, including improved cardiovascular health, reduced indicators of metabolic syndrome, improved musculoskeletal health, reduced risk of type 2 diabetes, and lesser symptoms of depression and anxiety (Janssen & LeBlanc, 2010). A growing body of research has investigated the environmental influences on children's physical activity (Cervero & Kockelman, 1997; Lovasi, Grady, & Rundle, 2011; Sallis, Owen, & Fisher, 2008). In particular, this body of research has highlighted that greenspace provides an activity and health promoting environment (Fjørtoft & Sageie, 2000; Ord et al., 2013; Wolch et al., 2011). Greenspace is commonly defined as any open piece of land that is publically accessible and is partly or completely covered with grass, trees, or other vegetation (United States Environmental Protection Agency, n.d.). Research on greenspace has generally found a positive correlation between time spent in greenspaces and children's physical activity (Lachowycz & Jones, 2011).

Recent technological advancements have enabled the collection of objective, high-resolution data for research into individual's greenspace exposure and activity levels. One such study used portable GPS receivers and accelerometers to record positional and activity data from children during their free time (Almanza et al., 2012). This study found that children were 34-39% more likely to engage in MVPA when in greenspaces compared to non-greenspaces. Different researchers using the same technology found that children were 37% more likely to engage in MVPA

when in a greenspace compared to non-greenspace (Wheeler et al., 2010). This particular study found that children only spent 2% of their after school time in greenspaces, however that this environment accounted for 9% of MVPA for boys and 6% of MVPA for girls.

A different body of research suggests that physical activity and greenspace exposure may be independently associated with other important aspects of childhood development, such as cognitive function, emotional wellbeing, and propensity towards risk-taking (Bonhauser et al., 2005; Faber-Taylor et al., Sullivan, 2002; Janssen & LeBlanc, 2010; Nelson & Gordon-Larsen, 2006; Tomporowski et al., 2008; Wells, 2000). The research linking children's greenspace exposure and cognitive development mostly consists of small, exploratory studies; however, this literature suggests small, positive associations exist between greenspace exposure and attentional capacity (Faber-Taylor et al., 2002, Wells, 2000). Furthermore, a literature review in 2008 concluded that there is a positive association between children's physical activity levels and their executive function (Tomporowski et al., 2008).

With regard to the relationship between physical activity and emotional health in children, observational studies have generally reported small to modest associations between physical activity and depressed mood (Janssen & LeBlanc, 2010). In contrast, experimental research has tended to report beneficial effects of exercise interventions on the symptoms of both anxiety and depression (Annesi, 2005; Bonhauser et al., 2005; Norris et al., 1992). Greenspace exposure has also been associated with greater emotional wellbeing in children, as indicated by lower self-rated measures of emotional distress found in children living in 'greener' neighbourhoods (Wells & Evans; 2003). However, conversely, a large survey of Canadian children found no

consistent relationships between neighbourhood greenspace and emotional wellbeing (Huynh et al., 2013). Theorists have also proposed an association between time spent in greenspace and the formation of healthy attitudes towards risk-taking (Louv, 2005). However, there has been no empirical research to test this hypothesis. Similarly, the associations between children's physical activity levels and their propensity to take risks has received very little research attention. A single study reported that children who participated in a wide range of sporting activities had lower self-reported levels of high-risk behaviours; however, this effect was highly mediated by parental involvement in sports activities (Nelson & Gordon-Larsen, 2006).

The current study seeks to address the aforementioned research gaps by combining accelerometry, GPS, and GIS to provide objective, high-resolution information on children's physical activity and location. Building on other studies that have used this methodology (Almanza et al., 2012; Wheeler et al., 2010), we add direct and validated measures of cognitive development, emotional wellbeing, and risk-taking behaviour. This methodology allows quantitative analysis of the relationship between greenspace exposure and physical activity, as well as enabling investigation into other important variables which contribute to healthy childhood development.

## **4.2 Methods**

**4.2.1 Participants.** A total of 118 participants (48 boys, 70 girls) aged 11 to 14 years were selected from three intermediate schools in the Auckland region of New Zealand. Inclusion criteria included: 1) students enrolled in school years 7 or 8, 2) appropriate English language comprehension. Exclusion criteria included: 1) physical disability that impaired mobility, 2) cognitive impairment likely to affect the ability to



complete testing. Written informed consent and assent was obtained for all participants. Ethical approval for this study was granted by the Auckland University of Technology Ethics committee.

#### **4.2.2 Measures**

***Greenspace exposure.*** Locational data were gathered using the Qstarz BT-Q1000XT GPS receiver (Qstarz International, <http://www.qstarz.com>, Taipai, Taiwan) which was worn on a waist belt during the monitoring period and configured to record data every 15 seconds. The accuracy and suitability of these devices has been established in previous research (Duncan et al., 2013; Schipperijn et al., 2014). Participants were given verbal and written instructions regarding use of the device and a diary to record non-wear time.

***Physical activity.*** Physical activity frequency, duration, and intensity were measured using the Actigraph GT3X+ accelerometer (Actigraph, <http://www.actigraphcorp.com>, Pensacola, FL). The accuracy and count thresholds for these devices have previously been validated for use with children against indirect calorimetry (Evenson et al., 2008; Trost et al., 2011). These were also worn on the supplied belt and verbal and written instruction on correct use of the device was given similar to the GPS receiver. Non-wear time, defined as 60 minutes of consecutive zero counts, was removed from the data using Actilife software (National Cancer Institute, n.d.). GPS data and accelerometer data were merged using the Personal Activity Location Measurement System (PALMS) which codes each GPS waypoint with the intensity of movement at that particular location (Kerr et al., 2011). The merged data streams retrieved from PALMS were imported into GIS for spatial analysis using ArcGIS software. (ESRI ArcMap 10.2.1).

***Physical measures.*** The standing height of each participant was measured to the nearest millimetre with a portable stadiometer (Design No. 1013522, Surgical and Medical Products, Seven Hills, Australia), and weight was measured to the nearest 0.1 kg on a digital scale (Model Seca 770, Seca, Hamburg, Germany). BMI was then calculated as weight (kg) divided by squared height (m<sup>2</sup>). In addition, waist circumference measurements were made at the highest point of the iliac crest at minimal respiration, and the waist to height ratio (WHtR) was calculated.

***Emotional wellbeing.*** Wellbeing was assessed with three different self-report measures. The Life Satisfaction Scale (LSS) is a 5-item questionnaire derived from Hubener's Student Life Satisfaction Scale (Huebner, 1991). Participants also completed the TDIW which asks the participant to rate their happiness in ten different life domains on a scale from 0 to 10, which are then summed to give an aggregate wellbeing score between 0 and 100 (Rees et al., 2010). Lastly we included a single item measure of happiness with life as a whole (HS) measured on a scale from 0 to 10. These three scales have been used in large research projects in this age group in England and all have been shown to exhibit good levels of reliability and stability (Rees et al., 2010).

***Sensation-seeking.*** Sensation-seeking is a personality trait characterised by the need for varied, novel, and complex sensations and experiences, and the willingness to take physical and social risks for such experiences (Zuckerman, 1990). This was measured using the Short Form Sensation-seeking Scale (SFSSS) (Stephenson et al., 2003). This scale consists of four items which relate to the four domains of sensation-seeking (disinhibition, experience-seeking, boredom susceptibility, and thrill-

seeking). In research with 5000 children aged 11-15, scores on the SFSSS were found to correlate well with the results of a more comprehensive and well validated 40 item scale (Stephenson et al., 2003; Zuckerman et al., 1978). SFSSS scores were also found to correlate with established risk-taking behaviours such as illicit drug use (Stephenson et al., 2003).

***Risk-taking.*** Risk-taking behaviour was assessed using the youth version of the Balloon Analogue Risk Task (BART-Y), a computer-based behavioural measure designed to reflect elements of risk-taking present in the natural environment (Lejuez et al., 2007). The BART-Y has been shown to correlate with real world risk-taking behaviours in adolescents (Lejuez et al., 2007; Lejuez et al., 2002). Using a behavioural measure of risk-taking avoids the limitations of self-report measures which may arise from the perceived negative consequences of reporting risky behaviour and participant's possible lack of insight into their risk-taking (Lejuez et al., 2002).

***Cognitive development.*** Computerised neurocognitive testing was conducted using CNS Vital Signs (CNS-VS, [www.cnsvs.com](http://www.cnsvs.com)), a web-based battery of seven tests that are frequently used in neuropsychological analysis and have well-established reliability and validity (Gualtieri & Johnson, 2006). From the results of these tests, CNS-VS calculates the subject's performance in the following cognitive domains; visual memory, verbal memory, processing speed, psychomotor speed, reaction time, cognitive flexibility, and executive function. The results of the CNS-VS test battery have been shown to correlate highly with conventionally administered neurocognitive testing and also show good levels of test-retest reliability in participants aged from 7-90 (Gualtieri & Johnson, 2006).

**4.2.3 Procedures.** Data collection for this observational study took place between September and December 2014. Students completed surveys, performed computerised testing, and had physical measures taken by a trained research assistant. They were then fitted with a GPS and accelerometer device to wear for the next 7 day period and given an activity diary to fill in over this time. Both verbal and written instructions in use of the devices was given at this time. At the conclusion of the monitoring period, the devices and diaries were collected from participants.

**4.2.4 Data Analysis.** Data analysis took place during February to May 2015. GIS mapping of the GPS data against the parks dataset available through Open Street Map ([www.openstreetmap.org](http://www.openstreetmap.org)) allowed the identification of time points located within greenspaces. The percentage of total data points inside greenspaces for each participant was calculated. Four independent generalised linear mixed model (GLMM) structures were used to quantify the relationships among the measured variables while accounting for variations in the data from both fixed and random effects. All models specified child nested within school as a random effect.

Model 1: Each of the outcome variables (emotional wellbeing, cognitive domain scores, risk-taking, sensation-seeking, and physical health measures) were entered (individually) as fixed effects in a series of GLMMs with the percentage of time spent in greenspace as the dependent variable and sex, age, and school included as covariates.

Model 2: Identical structure to Model 1 with the exception of percentage of time spent in MVPA entered as the dependent variable.

Models 3 and 4: Repetition of Models 1 and 2 with percentage of time spent in MVPA (Model 3) and greenspace (Model 4) entered as fixed effects.

The latter two models were included to investigate the relative strength of the effects of MVPA and greenspace exposure on the outcome variables. All analyses were conducted using SPSS software (SPSS v22).

### 4.3 Results

Of the 118 participants, valid accelerometer data were collected from 108, and valid GPS data from 72 participants. Table 1 displays the descriptive statistics relating to the study sample.

*Table 1: Descriptive Statistics*

		<b>Male</b>	Std Dev	<b>Female</b>	Std Dev	<b>All</b>	Std Dev
Number		44		64		108	
Age	Years	12.75	0.52	12.79	0.48	12.77	0.49
BMI		19.17	2.79	19.70	3.15	19.48	3.01
WHtR		0.44	0.04	0.43	0.04	0.44	0.04
% time in greenspace		1.53%	1.87%	0.90%	1.24%	1.17%	1.56%
Average min/day in	Sedentary	381.15	94.11	393.44	93.50	388.43	93.51
	Light	144.26	37.42	136.31	37.84	139.55	37.70
	Moderate	28.26	8.14	24.69	8.86	26.14	8.72
	Vigorous	20.97	11.15	15.69	10.46	17.84	11.01
	MVPA	49.23	17.01	40.38	17.37	43.98	17.69
% time in MVPA		8.71%	2.79%	7.19%	2.86%	7.81%	2.91%

There were slightly more female (59%) participants, and the average age was 12.8 years. Over the course of the week on average participants spent 1.17% of monitored time in greenspace. Male participants spent 1.53% of their monitored time in greenspace compared to 0.9% for females, a difference that was not significant ( $p = 0.090$ ). Overall the average daily time in MVPA was 44.0 minutes, which was 7.81% of the monitored time. Males spent a greater proportion of time in MVPA, with an average of 49.2 min/day in MVPA, compared to 40.04 min/day for Females ( $p = 0.008$ ). Only 27.3% of males and 15.6% of females in this study met the New Zealand Ministry of Health guidelines of 60 minutes of MVPA per day (Ministry of Health, n.d.). Despite the relatively low proportion of time spent in greenspace, mean activity counts per epoch were much higher during time in greenspace (282) compared to non-greenspace readings (51) ( $p = 0.002$ ). Results also indicated that 7.07% of total weekly activity counts occurred during the 1.17% of time in greenspace.

The results of the four generalised linear mixed models are displayed in Table 2. Each model shows the associations between each of the outcome variables against; percentage of monitored time in greenspace (column 1); percentage of monitored time in MVPA (column 2); time in greenspace adjusted for MVPA (column 3); and time in MVPA adjusted for greenspace exposure (column 4).

Table 2: Generalised linear mixed models

		Model 1: Greenspace exposure			Model 2: Percentage time in MVPA			Model 3: Greenspace exposure adjusted for MVPA			Model 4: MVPA adjusted for greenspace exposure		
	Unit	Beta	95% CI	p value	Beta	95% CI	p value	Beta	95% CI	p value	Beta	95% CI	p value
Percentage of time in MVPA	%	<b>0.951</b>	<b>0.467-1.435</b>	<b>0</b>									
Life Satisfaction score	LSS	<b>0.861</b>	<b>0.458-1.264</b>	<b>0.000</b>	<b>0.528</b>	<b>0.330-0.726</b>	<b>0.000</b>	<b>0.661</b>	<b>0.368-0.955</b>	<b>0.000</b>	<b>0.181</b>	<b>0.006-0.355</b>	<b>0.042</b>
Happiness score	HS	<b>0.445</b>	<b>0.177-0.713</b>	<b>0.001</b>	<b>0.225</b>	<b>0.113-0.338</b>	<b>0.000</b>	<b>0.363</b>	<b>0.171-0.554</b>	<b>0.000</b>	0.038	-0.206	0.466
Ten Domain Index of Wellbeing score	TDIW score	<b>3.176</b>	<b>1.487-4.865</b>	<b>0.000</b>	<b>2.561</b>	<b>1.750-3.372</b>	<b>0.000</b>	<b>2.670</b>	<b>1.29-4.050</b>	<b>0.000</b>	0.397	-1.931	0.415
Waist/Height ratio	W/H ratio	-0.001	-0.011	0.586	-0.002	-0.006	0.253	-0.006	-0.013	0.089	0.002	-0.011	0.386
Body Mass Index	BMI	-0.232	-0.708	0.194	-0.197	-0.421	0.067	-0.312	-0.972	0.204	0.135	-0.829	0.518
Risk taking score	BARTY score	0.091	-3.806	0.924	<b>1.098</b>	<b>0.024-2.173</b>	<b>0.045</b>	0.298	-4.159	0.774	-0.187	-2.448	0.76
Sensation seeking score	SFSS score	-0.023	-0.806	0.910	<b>0.402</b>	<b>0.199-0.606</b>	<b>0.000</b>	0.125	-0.672	0.461	-0.027	-0.329	0.741

Boldface indicates statistical significance (p<0.05)

None of the models showed significant relationships between the independent variables and measures of cognitive development (not included in Table 2). In each column of Table 2, the Beta coefficient ( $\beta$ ) indicates the absolute change in each outcome variable for a 1% change in either greenspace exposure or time spent in MVPA. In Model 1, a significant relationship was detected between percentage of time in greenspace and the percentage of time in MVPA ( $B = 0.951$ ;  $p = 0.000$ ). Likewise, there were positive relationships between the proportion of time spent in greenspace and all three measures of emotional wellbeing (LSS  $\beta = 0.861$ ,  $p < 0.001$ ; TDIW  $\beta = 3.176$ ,  $p < 0.001$ ; HS  $\beta = 0.445$ ,  $p < 0.001$ ). However there were no significant relationships with any physical, risk-taking, or sensation-seeking measures. In Model 2, the percentage of time in MVPA was significantly associated with all measures of emotional wellbeing (LSS  $\beta = 0.528$ ,  $p < 0.001$ ; TDIW  $\beta = 2.561$ ,  $p < 0.001$ ; HS  $\beta = 0.225$ ,  $p < 0.001$ ), as well as risk-taking ( $\beta = 1.098$ ,  $p < 0.045$ ) and sensation-seeking ( $\beta = 0.402$ ,  $p < 0.001$ ) scores. There was a trend towards decreased BMI with increasing MVPA but this did not reach significance ( $\beta = -0.197$ ,  $p = 0.067$ ). No associations were detected between MVPA and WHtR. In Model 3, the strength of the associations between greenspace and emotional wellbeing were reduced but still significant (LSS  $\beta = 0.661$ ,  $p < 0.001$ ; TDIW  $\beta = 2.670$ ,  $p < 0.001$ ; HS  $\beta = 0.363$ ,  $p < 0.001$ ). In Model 4, a significant association remained between one of the measures of emotional wellbeing – life satisfaction - (LSS  $\beta = 0.181$ ,  $p = 0.042$ ), but not the other two - ten domain of wellbeing, or happiness with life - (TDIW  $\beta = 0.397$ ,  $p = 0.415$ ; HS  $\beta = 0.038$ ,  $p = 0.466$ ). Furthermore, the association between MVPA and both risk-taking and sensation-seeking present in Model 2 was not found in Model 4.



#### 4.4 Discussion

This study was the first to combine objective measures of physical activity and greenspace exposure with validated measures of cognition, emotional wellbeing, sensation-seeking, and risk-taking. This approach enabled analysis of several relationships that have not been previously investigated, such as the relative effects of greenspace and physical activity on emotional wellbeing and the hypothesized association between risk-taking and greenspace exposure.

On average, children in this sample only spent 1.17% of monitored time in greenspaces, a figure that is commensurate with previous research findings. For example, a study from the UK found that children spent 2% of their afterschool time in greenspaces (Wheeler et al., 2010). Nonetheless, greenspaces remain an important environmental context for physical activity with 7.07% of all activity counts taking place in greenspace. Mean accelerometer count per epoch in greenspace was  $\mu = 282$  (Std. dev. = 159) compared with 51 (Std. dev. = 7) in non-greenspace, a large difference of 231 counts. This provides further support for the theory that greenspace provides a supportive environment for increased MVPA and underscores the value of greenspace exposure in children's health promotion initiatives.

This study found a strong positive relationship between the proportion of time spent in greenspace and the proportion of time in MVPA: for every 1% increase in time in greenspace there was a 0.95% increase in MVPA. This finding is consistent with the majority of previous research in the field, although differences in measurement and analysis of variables make it difficult to directly compare results. A previous study found that each hour of time outdoors was associated with a 27 min/week and 21 min/week increase in MVPA for boys and girls respectively (Cleland

et al., 2008). However, this study did not measure time in greenspace specifically. Previous studies using similar methodology have reported that children were 34% (Almanza et al., 2012) or 37% (Wheeler et al., 2010) more likely to engage in MVPA when in a greenspace. The current research supports the hypothesis that greenspaces are highly supportive of increased physical activity.

A notable finding was that a child's level of greenspace exposure had a significantly stronger relationship with emotional wellbeing than their physical activity level. Indeed, each additional 1% of time spent in greenspace was associated with a 0.66 increase in life satisfaction score; by comparison, a 1% increase in MVPA was associated with a 0.18 increase in life satisfaction score. Furthermore, the Happiness and Ten Domain Index of Wellbeing scores were both significantly related to greenspace exposure, but not to physical activity. Previous studies have identified independent links between physical activity and emotional wellbeing (Annesi, 2005), and between greenspace exposure and emotional wellbeing (Wells & Evans, 2003). However, this study is the first to be able to differentiate the individual effects of greenspace and physical activity on wellbeing. These findings increase our understanding of the variables that contribute to children's emotional wellbeing and have implications for interventions aiming to increase overall wellbeing in children.

In addition, we found that the proportion of time spent in MVPA was significantly related to both sensation-seeking and risk-taking behaviour. This suggests that children who have an innate affinity for novelty, excitement, and risk-taking are naturally drawn towards physically active pursuits. Interestingly, no relationships were observed between greenspace exposure and either risk-taking or sensation-seeking. From this data it seems that children higher in sensation-seeking or

risk-taking are not more likely to seek out greenspaces as an environment conducive to novel experiences and risky behaviour.

We found no significant relationships between any of the physical measures taken (BMI and WHtR) and either MVPA or greenspace exposure. This result aligns with the findings of one existing study (Almanza et al., 2012), but stands in contrast to another (Wheeler et al., 2010), which did find a small but significant correlation. Additionally, no relationships were found between any of the cognitive measures and either greenspace exposure or average daily MVPA. While the existing research between these variables has yielded contradictory results, most of the positive relationships reported have either been from non-peer reviewed studies (Sibley & Etnier, 2003), or found only weak correlations (Carlson et al., 2008). More research on larger populations is needed to investigate the possible associations between physical health, cognitive development, and greenspace exposure.

A strength of the current study was the use of objective measures of physical activity and greenspace exposure. The results presented here add to the growing body of work that attempts to characterise the location of children's physical activity using advanced monitoring techniques. In addition, the study utilised well-validated, direct measures of cognitive development and risk-taking behaviour, and validated survey instruments for the measures of emotional wellbeing. The sample included three different schools from geographically and socioeconomically diverse neighbourhoods, and the students included covered a wide range of ethnicities, enhancing the generalisability of the results.

Several study limitations are noted however. Firstly, the sample size of 108 participants was relatively small; it is possible that there were meaningful associations that were not detected due to lack of statistical power. Secondly, all data were collected during term time from September to December 2014, and thus no conclusions can be drawn about seasonal variations in greenspace exposure or physical activity. Finally, the observational design of the study precludes any ability to infer causation from the findings.

As a whole this study reinforces previous research findings showing that greenspace exposure is associated with higher levels of MVPA in children. We also found an association between both risk-taking behaviour and the personality trait of sensation-seeking and engagement in MVPA. Although we found that emotional wellbeing was positively associated with both physical activity and greenspace exposure, we found that greenspace exposure had a significantly stronger relationship with all three of the wellbeing measures than physical activity. These findings further underscore the importance of time in greenspaces as a component of a physically and emotionally healthy childhood.

## **Chapter 5. Paper 2- The association between children's time spent in their neighbourhood and physical activity, BMI, and life satisfaction.**

### **5.1 Introduction**

Regular physical activity is associated with numerous health benefits in children including, reduced risk of obesity, cardiovascular problems, and diabetes, as well as improved emotional well-being (Jansen & LeBlanc, 2010; World Health Organisation, 2010). Evidence-based guidelines on physical activity recommend that children engage in at least 60 minutes per day of MVPA (Ministry of Health, n.d.; Strong et al., 2005); however, studies have repeatedly shown that most children are not meeting these targets (Clark et al., 2013; Troiano et al., 2008). These low levels of MVPA are likely to have considerable future impact given that the health behaviours established in childhood tend to persist into adulthood (Freedman et al., 2005; Kjonniksen, Torsheim, & Wold, 2008).

In order to effectively address this large and growing public health concern, researchers have sought to understand and quantify the factors that influence the physical activity of children. One of the variables that has been identified as a potential mediator of children's physical activity is the built environment (Davison, & Lawson, 2006; Sallis, Prochaska, & Taylor, 2000). The immediate neighbourhood environment in particular is of interest given the decrease in children's independent mobility over the past generation reported in recent literature (Bhosale et al., In Press; Fyhri et al., 2011; Pooley et al., 2005). A growing body of research has reported that children are spending more of their free time in indoors, sedentary, or in supervised activities, and less time active in their neighbourhood environment (Fagerholm & Broberg, 2011; Veitch et al., 2008; Villanueva et al., 2012; Wridt, 2010). The neighbourhood potentially provides an environmental context for physical activity, social interaction,

and development of independence, therefore investigation of its role in wider childhood development is warranted.

Physical neighbourhood variables that have been investigated in the literature include, access to parks, access to recreational facilities, land-use mix, residential density, street connectivity, walkability, sidewalks, traffic speed/volume, pedestrian safety structures, crime-related safety, and vegetation (Davison, & Lawson, 2006; Ding et al., 2011). However, studies relating these factors to physical activity have produced inconsistent findings. Ding et al (2011), in a review of this literature, report that the method of measurement of neighbourhood characteristics accounts for some of the variability in these findings. In studies which used subjective measures such as the perceived walkability, safety, or access to recreational facilities, these perceived neighbourhood variables were associated with physical activity in 60% of published studies. However, when objective measures of both physical activity and neighbourhood variables were used, significant relationships were reported only 33% of the time (Ding et al., 2011).

Children's relationship with their neighbourhood environment may also have been influenced by a range of technological, social, and cultural changes which have affected both the quantity, type, and location of children's activity. Technological changes have led to an increase in sedentary, home-based entertainment options, such as computers and television, which now occupy an increasing amount of children's leisure time (Clements, 2004; Karsten, 2005; Witten et al., 2013). Increased parental concern, as evidenced by the reported rise of 'helicopter parenting' (Somers & Settle, 2010), has also led to indoor supervised activity being seen as more desirable, and outdoor activity in the wider neighbourhood being seen as 'risky' (Clements, 2004;

Gray, 2011; Valentine & McKendrick, 1997). Social changes such as children's increased involvement in structured activities and increases in households where both parents work may have also led to children spending less free time in the neighbourhood and more time indoors, or being driven to locations outside their neighbourhood (Copperman & Bhat, 2010; Gray, 2011; Loebach & Gilliland, 2014; Mikkelsen & Christensen, 2009).

One reason that we know little about children's relationship with their neighbourhood environment is that complex objective measures are required to accurately investigate both physical behaviours and environmental exposures. Recent advancements in technology such as the development of portable GPS receivers and accelerometers have enabled collection of large sets of objective and accurate locational and activity data. Recent studies have utilised these technologies to give us a clearer understanding about children's patterns of activity around home, neighbourhood, and school environments. For example, Loebach and Gilliland (2014) used GPS receivers to monitor 143 Canadian children over a 7 day period. They found that children in their sample spent 75% of their out of school time in their neighbourhood. This study found that children varied considerably in their level of independent neighbourhood mobility, with almost a quarter of participants never actively travelling more than 400m from home and 15% not venturing more than 200m from home. However, this study did not incorporate accelerometry and so cannot answer questions about how this large amount of time spent within the neighbourhood may relate to physical activity or other correlates of childhood wellbeing.

The aforementioned research suggests that the neighbourhood is an environment in which children spend a high proportion of their time. There is clearly a need to better

understand the influence of this environment on children's activity and health. Therefore the aim of this study was to use a range of objective measures to explore the associations between the time children spend in their neighbourhoods and physical activity, BMI, time in greenspace, and life satisfaction. Furthermore, this study seeks to identify whether children's time spent in their neighbourhoods is associated with several physical characteristics of the neighbourhood (number and area of local greenspaces and walkability score), or with social variables such as the number of scheduled, structured activities children participate in each week.

## **5.2 Methods**

**5.2.1 Participants.** A total of 66 participants (26 boys, 40 girls) aged 11 to 14 years were selected from three intermediate schools in Auckland, New Zealand. These students were part of a larger study investigating the relationship between greenspace exposure and physical activity. Inclusion criteria included (1) appropriate English language comprehension and (2) enrolment in school years 7 or 8. Exclusion criteria included (1) cognitive impairment that would affect the ability to complete testing and (2) a physical disability that impaired mobility. Written informed consent and assent was obtained for all participants. Ethical approval for this study design was given by the Auckland University of Technology Ethics Committee.

### **5.2.2 Measures**

***Greenspace exposure.*** Geolocational data were gathered using the Qstarz BT-Q1000XT GPS receiver (Qstarz International, Taipai, Taiwan) worn on a waist belt during a 7-day monitoring period, and configured to record participants' geospatial location every 15 seconds. The suitability and accuracy of these devices has been



established in previous research (Duncan et al., 2013; Schipperijn et al., 2014). Participants were given verbal and written instructions regarding use and charging of the device and a diary to record non-wear time.

***Physical activity.*** Participants' frequency, duration, and intensity of physical activity over the 7-day monitoring period was measured using the Actigraph GT3X+ accelerometer (Actigraph, Pensacola, FL). Both the accuracy of these devices and validated count thresholds for use with children have previously been validated against indirect calorimetry (Evenson et al., 2008; Trost et al., 2011). These were also worn on the supplied belt and verbal and written instruction on their correct use was given as for the GPS receiver. Non-wear time, defined as 60 minutes of consecutive zero counts, was removed from the data using Actilife software.

***Physical measures.*** The weight of each participant was measured to the nearest 0.1 kg on a digital scale (Model Seca 770, Seca, Hamburg, Germany) and their standing height was measured to the nearest millimetre with a portable stadiometer (Design No. 1013522, Surgical and Medical Products, Seven Hills, Australia). BMI was then calculated as weight (kg) divided by height squared ( $m^2$ ).

***Emotional Wellbeing.*** Emotional wellbeing was assessed using the Life Satisfaction Scale (LSS), a 5-item questionnaire derived from Hubener's Student Life Satisfaction Scale (Huebner, 1991). This scale has been used in large surveys of emotional wellbeing in children of the same age range in England and has been shown to exhibit good levels of reliability and stability (Rees et al., 2010).

***Neighbourhood Walkability.*** Walkability is defined as the degree to which a built environment promotes walking behaviours (NZ Transport Agency, n.d.). Many environment variables have been investigated as potentially influencing people's walking behaviour including the presence of footpaths, neighbourhood crime rates, perceived safety, traffic volume, pollution, and proximity of neighbourhood amenities (Owen, Humpel, Leslie, Bauman, & Sallis, 2004). Walk Score ([www.walkscore.com](http://www.walkscore.com)) is a publicly available web-based application that calculates neighbourhood walkability based on proximity data available through Google Maps™. Two studies have reported moderate to strong associations between WalkScore results and GIS measured indicators of neighbourhood walkability in different US cities (Carr, Dunsiger & Marcus, 2011; Duncan, Aldstadt, Whalen, Melly, & Gortmaker, 2011).

**5.2.3 Procedures.** Data collection for this observational study took place between September and December 2014. Students completed survey instruments and had physical measures assessed by a trained research assistant. Students were then fitted with a GPS and accelerometer device to wear for the next 7 day period and given an activity diary to fill in for this period. At the conclusion of the monitoring period the devices and diaries were collected.

**5.2.4 Data Analysis.** GPS data and accelerometer data were merged using the Personal Activity Location Measurement System (PALMS) which codes each GPS waypoint with the intensity of movement at that particular location (National Cancer Institute, n.d.). Data was included in the analysis provided that participants had recorded at least three days of data with a minimum of four hours of valid data on each of these days. These inclusion criteria were used in previous research with a similar methodology (Almanza et al., 2012). Participants who lived at multiple addresses (e.g.

due to parental separation) and therefore did not have a single neighbourhood they were exposed to were also excluded from this analysis. The merged data streams retrieved from PALMS were imported into GIS for spatial analysis using ArcGIS Software. (ESRI ArcMap 10.2.1). GIS analysis allows the analysis and display of data with a spatial component and in this study allowed us to see how participant's activity differed in various environments and locations.

Participants' neighbourhoods were defined as an 800m radius around their primary home address. This definition has been used in previous research and shown to be a valid measure of a child's neighbourhood boundary (Austin et al., 2005; Ball, et al., 2006; Timperio et al., 2010; Villanueva et al., 2012). This buffer was mapped in ArcGIS and data points within the neighbourhood were separated for analysis. Subjects were divided into quartiles for analysis on the basis of the percentage of their total monitored time that they spent within the neighbourhood buffer. Quartile I represents the participants who spent the least amount of time in their neighbourhood, whereas quartile IV represents those who recorded the most in-neighbourhood time. Greenspaces within the neighbourhood buffer were identified using the Open Street Map parks dataset ([www.openstreetmap.org](http://www.openstreetmap.org)), which allowed the measurement of the area and number of greenspaces within each participant's neighbourhood buffer. School boundaries were visually identified and mapped on ArcGIS and data points within these boundaries were also separated for analysis.

Three separate analyses were employed. Analysis 1 investigated the associations between children's time in their neighbourhood and the independent variables of time in MVPA, BMI, LSS score, and proportion of time spent in greenspaces. Analysis 2 investigated any relationships between time children spent

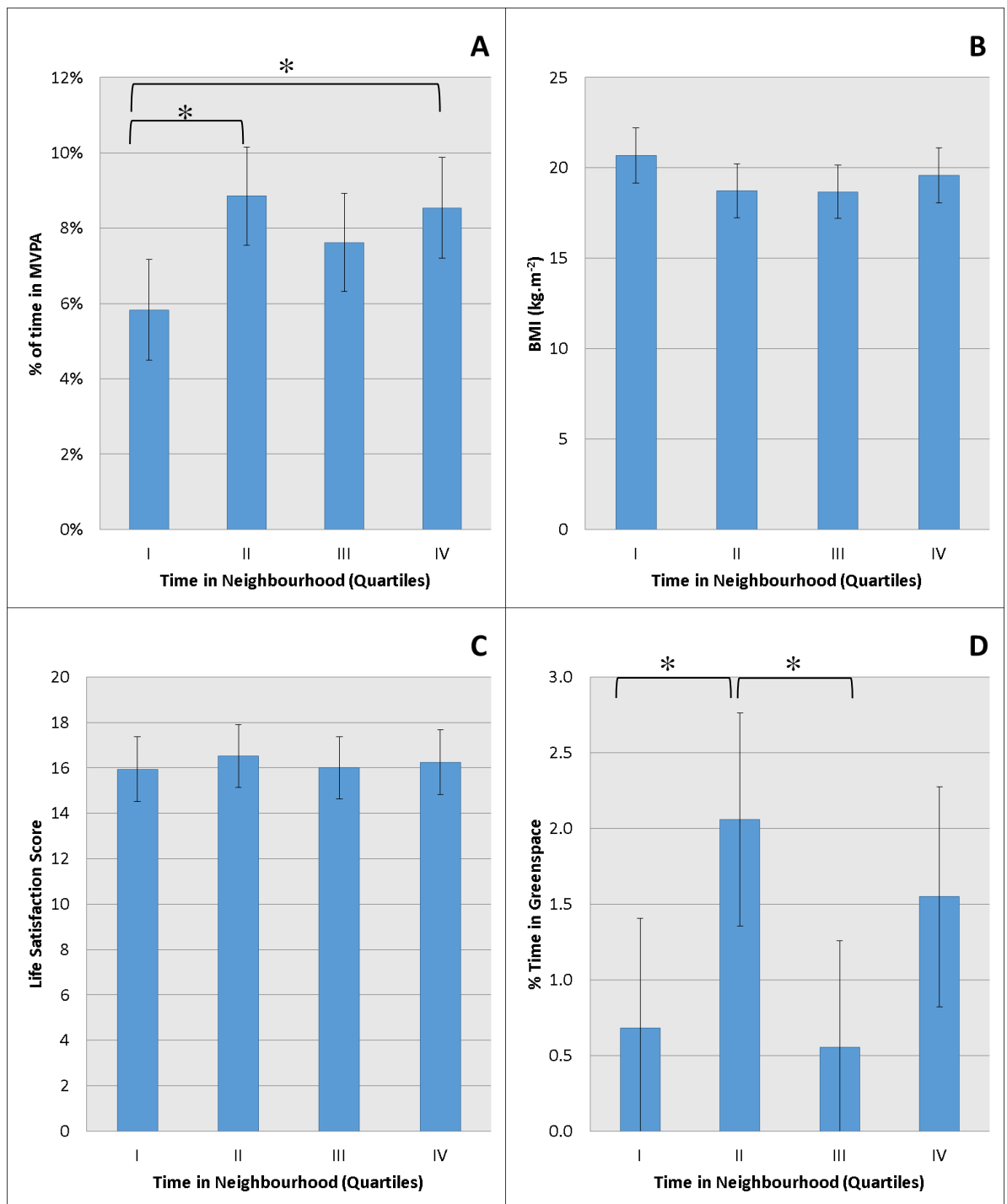
in their neighbourhood and physical properties of the neighbourhood (area of greenspace, number of greenspaces, and neighbourhood walkability score) or the number of structured, weekly, extracurricular activities children participated in. For analyses 1 and 2, generalised linear models were used to investigate the association between the quartiles of time in neighbourhood and each of the other variables. Initially the models were adjusted for participant's age and sex, but these factors were not significant and so were removed from the final analysis. Analysis 3 investigated the effect of the school environment on children's average activity levels, and specifically investigated the influence of the child's school being within their neighbourhood buffer on their in-neighbourhood activity. For this analysis the data points from within the school buffer were compared with those from the neighbourhood buffer and mean activity counts compared using paired sample t-tests. The effect of having a school in the participant's neighbourhood on neighbourhood activity was investigated by producing generalised linear models using data that were either unadjusted or adjusted for the presence of a school in the neighbourhood. All statistical analyses were conducted using SPSS software (SPSS version 22).

### **5.3 Results**

GPS and accelerometer data was collected from 78 participants. Of these, six datasets were excluded due to insufficient data, a further five were excluded due to participant's living at more than one address, and one was excluded due to submitting an invalid home address. This left 66 sets of data which were progressed into the analysis. Figure 1 shows the relationships between the quartiles of time spent in the neighbourhood and the individual variables investigated. These included the

percentage of monitored time spent in MVPA; BMI; LSS score; and the percentage of time participants spent in greenspaces.

Figure 1: Generalised linear models associating time in neighbourhood with individual variables



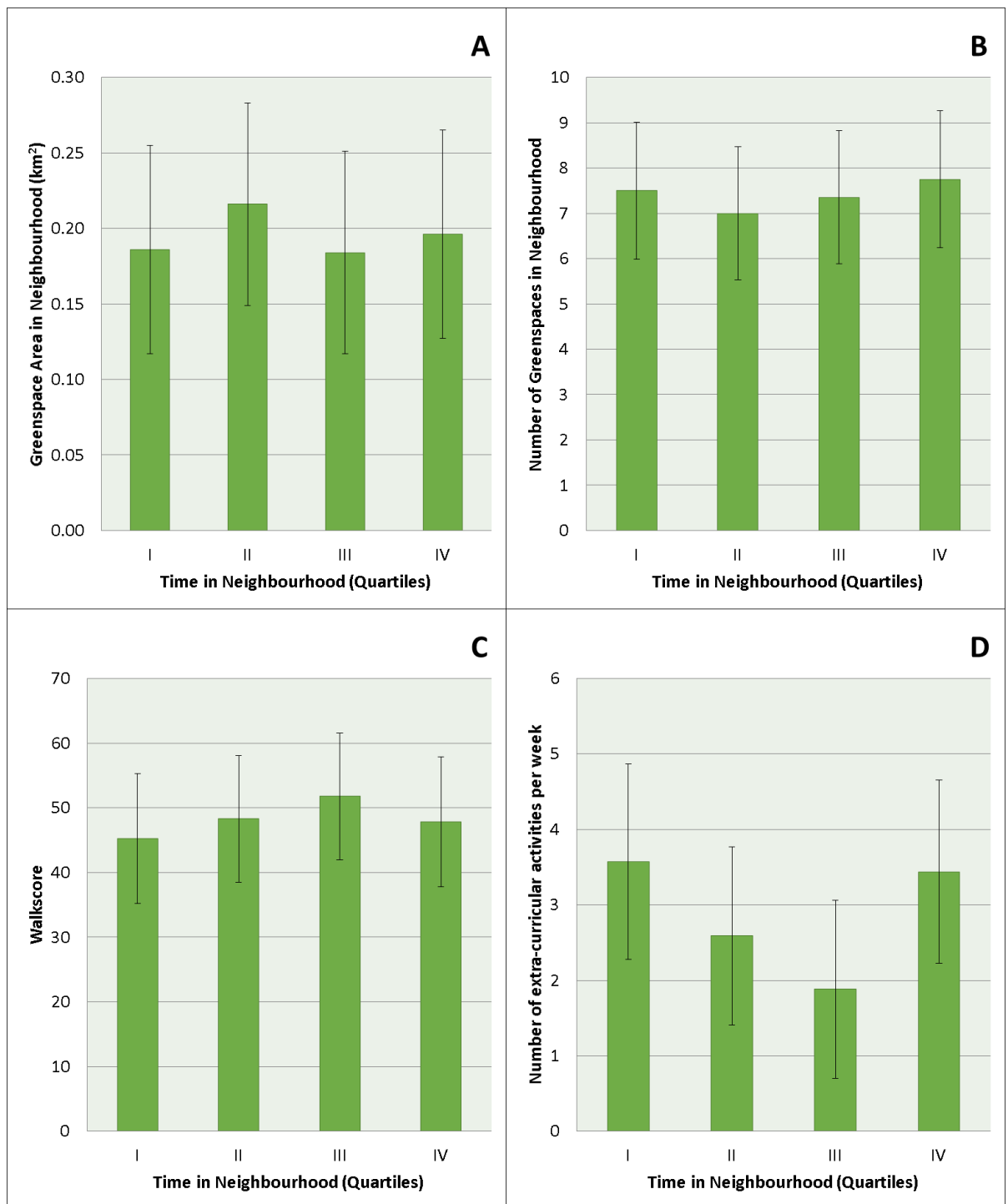
\* indicates  $p < 0.05$

(Data displayed as mean  $\pm$  SD)

Results of the generalised linear model showed that participants in the lowest quartile for time spent in their neighbourhoods spent a significantly lower percentage

of time in MVPA than those in the 2<sup>nd</sup> and 4<sup>th</sup> quartiles (Figure 1A). However, there was no significant difference in percentage of time in MVPA between the 1<sup>st</sup> and 3<sup>rd</sup> quartiles or between any other quartiles. As shown in Figure 1B and 1C, there was no significant difference between time spent within the neighbourhood and either BMI or LSS score. The association between time in neighbourhood and participants' exposure to greenspace showed that participants in quartile II spent a significantly greater percentage of time in greenspaces than those in quartiles I and III, but not quartile IV (Figure 1D). There were no other significant differences between quartiles.

Figure 2: Generalised linear models associating time in neighbourhood with neighbourhood variables



(Data displayed as mean  $\pm$  SD)

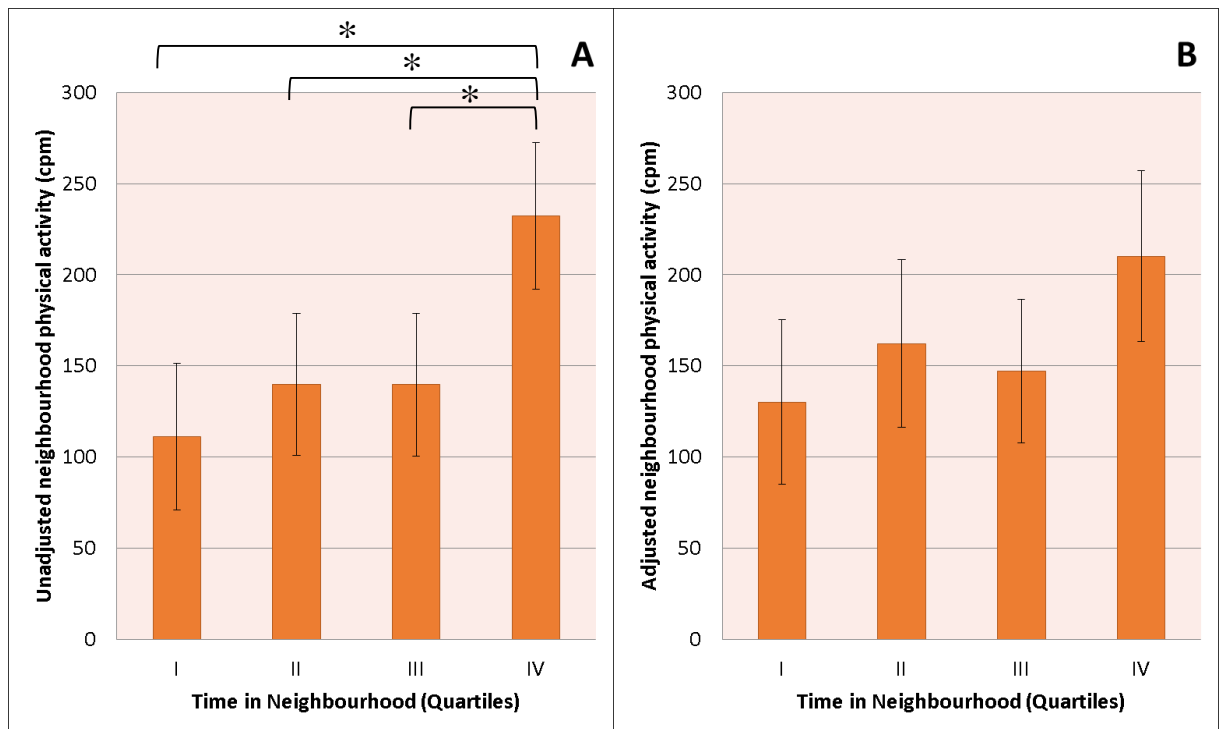
The second analysis shown in Figure 2 showed no significant relationship between time spent in the neighbourhood and any of the measured variables: area of



neighbourhood greenspace (Figure 2A), number of neighbourhood greenspaces (Figure 2B), or walkability score of home address (Figure 2C). Likewise, there were no significant differences in the number of weekly extra-curricular activities that children engaged in and between any of the four quartiles of time in neighbourhood (Figure 2D).

Our final analysis investigated the presence of a child's school within their neighbourhood buffer as a possible confounding variable. The school environment was found to be highly associated with increased physical activity. Average recorded activity in the school environment was 445.12 (Std. Dev. = 182.87) accelerometer counts per minute (CPM) compared to average neighbourhood activity of 155.32 CPM (Std. Dev. = 94.68;  $p < 0.001$ ). The net result of this was that children ( $n = 24$ ) whose school was located within their neighbourhood exhibited significantly higher average activity within their neighbourhood (211.02 CPM) than those who attended a school outside their neighbourhood ( $n = 42$ ; mean = 123.49 CPM;  $p < 0.001$ ). While the generalised linear model revealed that children in the upper quartile (IV) for time in neighbourhood had significantly higher average neighbourhood activity than for all other quartiles (Figure 3A), once the data were adjusted for the presence of schools within neighbourhood buffers, this association disappeared (Figure 3B).

Figure 3: Generalised linear models showing neighbourhood physical activity unadjusted (A) and adjusted (B) for the presence of participant's school in their neighbourhood



\* indicates  $p < 0.05$ .

(Data displayed as mean  $\pm$  SD)

## 5.4 Discussion

Whereas previous research has focussed on specific physical, social, or environmental aspects of the neighbourhood environment and their relationships with physical activity, this study investigated the role of the neighbourhood as an exposure in its own right. Using the time children spend in their neighbourhoods as a variable is a novel way of investigating a broader question about the influence of the neighbourhood on children's healthy development. Support for the neighbourhood as an activity-promoting environment was found by the comparison of the time in neighbourhood quartiles with overall weekly MVPA levels. In this comparison, the children who spend the least time in their neighbourhood engaged in significantly less MVPA than those who spend more time. A possible reason for this finding could be

that children who spend more time out of their neighbourhoods also spend more time in passive transport to and from these out-of-neighbourhood locations. In contrast, we found no significant relationship between the time spent in neighbourhood and children's BMI. This finding is consistent with previous research that has largely found no associations between children's BMI and neighbourhood level variables (Crawford et al., 2010; Kligerman, Sallis, Ryan, Frank, & Nader, 2007), which, in turn, appears to preclude any relationship between BMI and the time spent in the neighbourhood.

In line with previous research (Beighle, Erwin, Morgan, & Alderman, 2012; Cox, Schofield, Greasely & Kolt, 2006), our data showed that the school environment was a location in which children accrued a large proportion of their total daily activity. As a consequence, the presence of a child's school within their neighbourhood boundary is likely to affect any estimates of within-neighbourhood physical activity. In our dataset, a significant association between time in neighbourhood and increased physical activity within the neighbourhood was observed, but only when the presence of a school within the participant's neighbourhood was not accounted for. Children who attended a school within their neighbourhood showed two noticeable trends. Firstly, because their time at school took place within the neighbourhood, they tended to record greater amounts of time in the neighbourhood and thus were disproportionately represented in quartile IV. Secondly, because the school environment was associated with higher average activity, their average within-neighbourhood physical activity was elevated. Once the model was adjusted to account for participants whose school was located inside their neighbourhood buffer, the association between time in neighbourhood and average neighbourhood activity was non-significant. Identifying the presence of a child's school in their neighbourhood as

a potentially significant mediator of their neighbourhood physical activity is a finding that has important implications for further research in this area.

Another hypothesis was that time spent in the neighbourhood may be indicative of a broader lifestyle pattern that related to children's emotional wellbeing. For example, children who are regularly driven to various destinations outside of their neighbourhood (sporting events, shopping malls etc.) may experience less of the social connectivity and local interactions that come with roaming the neighbourhood. However our results do not support this hypothesis: the data showed that children who participated in a greater number of extra-curricular activities did not spend less time in their neighbourhood. Similarly, our data indicated that there was no significant relationship between time spent in the neighbourhood and reported life satisfaction, a major predictor of overall wellbeing. Life satisfaction is a product of a large number of factors and it is conceivable that a broad measure such as time in neighbourhood lacks any significant connection with life satisfaction.

Our analysis of the associations between time spent in the neighbourhood and the proportion of time spent in greenspace returned mixed results. Participants in quartile II had significantly greater exposure to greenspace than those in quartile I and III, but there were no other differences between any quartiles. It is difficult to discern a meaningful pattern within these findings, suggesting that the significant relationships may be coincidental. Previous research (Almanza et al., 2009; Wheeler et al., 2010) has reported positive associations between time spent in greenspace and physical activity; however, subsequent analysis of the current data found no significant relationship between the amount of greenspace in each participant's neighbourhood and the amount of time they spent in greenspace. This indicates that despite the

association between time in greenspace and physical activity, the amount of neighbourhood greenspace is unlikely to mediate this relationship.

We were also unable to find any significant associations between time spent in neighbourhood and area of greenspace in the neighbourhood, the number of greenspaces in the neighbourhood, or the neighbourhood walkability score. As discussed earlier, the existing literature linking neighbourhood variables with behavioural outcomes is highly varied, with some studies reporting positive associations but most studies reporting no associations. The findings of the present study concur with the majority of this previous research – at least for the variables that were assessed. Nonetheless, the inclusion of data from the online Walkscore system was a novel aspect of the study. Previous research has found that Walkscore estimates (produced by an algorithm utilising the Google Maps™ dataset) are moderately correlated with scoring generated by established GIS measures of neighbourhood walkability (Carr et al., 2010; Duncan et al., 2011). To our knowledge, this is the first study to compare Walkscore's walkability data with objective measures of neighbourhood activity. Despite the failure to find any significant associations in the latter analyses, the availability of an automated, open-source walkability measure is a potentially useful asset for researchers and further research is warranted.

This study had several notable strengths. In particular, the use of objective measures for almost all of the variables removes a large source of potential subjective bias. Another strength of the current study was the use of a monitoring period that included both weekday and weekend days. Several weaknesses of the study are also noted. The relatively small sample size limited the statistical power of the comparisons: in several procedures trends towards significance were noted and a larger

study sample may have revealed additional significant findings. Although the gathering of high quality objective physical activity data by accelerometry is a strength of this study, it is also noteworthy that use of accelerometry makes the accuracy of the data vulnerable to participant's non-wear time patterns. For example, participants may have been more likely to remove the devices for some sporting activities (such as contact sports or water-based activities) that may be more likely to occur outside of the neighbourhood, potentially confounding the associations.

This study adds to the mixed and inconclusive body of existing literature investigating the effect of children's environment on their physical activity. Despite ongoing research, utilising increasingly sophisticated methods, the relationships between neighbourhood variables and physical activity in children remain unclear. This study found some evidence that the time in the neighbourhood environment is positively associated with children's physical activity levels, but not associated with BMI, life satisfaction, or exposure to greenspace. Furthermore our neighbourhood level analysis found no relationships between time spent in the neighbourhood and either the area or number of local greenspaces or the neighbourhood walkability score. Once time in school was accounted for, spending more time in the neighbourhood did not relate to any increase or decrease in children's average physical activity within their neighbourhood. It seems likely that children's physical activity is not consistently related to isolated neighbourhood factors, but is influenced by a combination of individual, social, and environmental factors. Given the importance of childhood physical activity, and the need to understand the factors that support or undermine it, more research with a broader consideration of variables is warranted.

## Chapter 6: Discussion

The research presented in this Thesis investigated children's physical activity and how it is related to variables such as exposure to greenspace and the amount of time spent in the neighbourhood environment. While the findings are largely aligned with previous studies in this field, the addition of several novel measures within the study has allowed the investigation of questions that have not been previously investigated. This chapter will firstly present the findings of the research (6.1). The questions raised by the research, and possible future avenues for investigation will be outlined (6.2), and both the strengths and limitations of these studies will be discussed (6.3). Finally, the conclusions from the Thesis will be presented (6.4).

### 6.1 Findings

The paper presented in Chapter 4 examined the relationship between children's exposure to greenspaces and their physical activity, emotional wellbeing, cognitive development, and risk-taking behaviour. A strong significant association between greenspace exposure and children's MVPA levels was found ( $\beta = 0.951$ ,  $p < 0.001$ ). This result is aligned with previous studies that have used objective measures of children's activity and location (Almanza et al., 2012; Wheeler et al., 2011), and provides further evidence for the value of greenspace as an environment associated with increased physical activity in children. Aside from agreeing with their primary findings, this study also aligns with previously published papers in demonstrating the value of GPS and accelerometer devices in health research (Krenn et al., 2011; Puyau et al., 2002). Earlier research, which of practical necessity has relied on self-report measures of both activity and environmental exposure, has produced equivocal results. An earlier systematic review of the literature in this field found that of 50 studies

investigating associations between physical activity and time in greenspaces, 20 articles showed positive associations, 20 articles reported mixed findings, nine studies showed non-significant associations, and one showed a negative relationship (Kaczynski & Henderson, 2007). While the use of GPS receivers and accelerometers is still relatively new in health research, it appears that the use of this technology is allowing more accurate and consistent quantification of both environmental exposures and patterns of activity. Hopefully, as more research with objective and high-resolution measures is performed, a greater consensus on the strength of association between environmental exposures and health behaviours will emerge in the literature.

This paper also found that increased greenspace exposure was associated with greater emotional wellbeing as measured by all three separate wellbeing scales (LSS  $\beta = 0.861, p < 0.001$ ; TDIW  $\beta = 3.176, p < 0.001$ ; HS  $\beta = 0.445, p < 0.001$ ). This result lends support to previous research linking exposure to natural environments and emotional wellbeing in children (Wells & Evans, 2003). Life satisfaction as measured by the LSS was found to be related to both greenspace exposure and physical activity; however, its relationship with greenspace exposure ( $\beta = 0.661, p < 0.001$ ) was stronger than its relationship with MVPA ( $\beta = 0.181, p = 0.042$ ). The other measures of emotional wellbeing (TDIW, HS) were not associated with MVPA. The ability to detect these differential effects of greenspace exposure and physical activity on emotional wellbeing was a novel and useful aspect to this research, and although these results should not be interpreted as showing a causative relationship between greenspace exposure and emotional wellbeing, they do suggest a role for time in greenspaces as part of children's healthy development.



A further novel aspect of this research was the investigation of the individual traits of sensation-seeking and risk-taking and their associations with greenspace exposure and physical activity. Both of these personality traits were positively associated with children's MVPA (BART-Y score  $p = 0.045$ ; SFSS score  $p < 0.001$ ) but not with their level of greenspace exposure (BART-Y score  $p = 0.924$ ; SFSS score  $p = 0.910$ ). It has been proposed that greenspaces are a valuable environment for children to develop a healthy approach to risk-taking (Barker, 2004), and although the current research neither supports nor refutes this claim, no evidence was found that children with differing tolerance for risk spent any more or less time in greenspaces. The positive association between both sensation-seeking and risk-taking and children's time in MVPA is also a novel finding. Much of the research into these personality traits has involved linking them with negative health behaviours, and indeed there is evidence that both traits are correlated with high-risk health behaviours, such as drug and alcohol use, early sexual activity, and seat-belt non-use (Lejuez et al., 2007; Stephenson et al., 2003; Willis et al., 1994). In finding these same traits associated with the positive health behaviour of increased physical activity, this study highlights the fact that risk-taking and sensation-seeking have a more nuanced connection to overall health and wellbeing. Especially with the recent rise in 'helicopter parenting' (Somers & Settle, 2010) and the 'risk-averse society' (Lester & Maudsley, 2007), a more balanced consideration in the role that these traits play in overall childhood development may be timely.

The neurocognitive measures gathered through the CNS-VS application were not found to be associated with either greenspace exposure or physical activity levels in this study. As will be discussed further in Section 6.3.1, variation in the suitability of the testing environment between schools may have affected the completeness and

validity of this data. Of the total number of domain scores calculated from all participants, 8% of the results were invalid due to incorrect test performance. There is no available data on what constitutes an acceptable level of data completeness for CNS-VS in this age group; however, this relatively high level of incorrect test performance may have impaired the studies ability to detect any possible associations between cognitive skill and other variables.

The second paper presented as part of this Thesis (Chapter 5) investigated the relationship between the amount of time that children spend within their neighbourhood environment and their physical activity levels, as well as several other individual and neighbourhood level variables. This paper found weak evidence that time spent in the neighbourhood environment was associated with increased MVPA in children. Children in the lowest quartile for time spent in their neighbourhood exhibited lower proportions of time spent in MVPA than those in the second and fourth quartiles ( $p < 0.05$ ); however, no differences were detected between any other quartiles. No significant relationships were found between time spent in the neighbourhood and children's BMI or life satisfaction score. The association between time spent in the neighbourhood and children's greenspace exposure was unclear. Participants in the second quartile for time in neighbourhood had significantly higher levels of greenspace exposure than those in the first and third quartiles ( $p < 0.05$ ). However there were no other differences in greenspace exposure between any quartiles. It is hard to explain this result aside from chance. As will be discussed in Section 6.3.2, a weakness of this research project was the low sample size for the GPS data. This increases the possibility of spurious findings due to outlier effects, and possibly accounts for this result.

None of the neighbourhood level variables investigated (number of neighbourhood greenspaces, area of neighbourhood greenspaces, and neighbourhood walkability) showed any association with time spent in the neighbourhood. The existing body of research in this field has generally sought to associate specific variables within the neighbourhood with children's physical activity. This research has been equivocal, but the majority of research has failed to find clear relationships between any neighbourhood variable and children's overall activity levels (Ding et al., 2011). In the current study, the use of the amount of time children spent in their neighbourhood as the target variable represents a novel approach. However, this research also found very few significant associations between any of the variables measured and children's time in their neighbourhood. Taken in the larger context of research in this area it seems likely that, in general, the neighbourhood environment does not play a significant or consistent role in influencing children's engagement in physical activity.

This study also included a social variable, namely the number of extracurricular activities participants' engaged in per week. Previous research has shown that children are spending more time in structured activities and consequently less time in unstructured free play around the home and neighbourhood (Gray, 2011). However, no research has been conducted investigating what effect this may have on children's exposure to their own neighbourhood. The current research found no association between the number of extra-curricular activities a child engaged in per week and the amount of time they spent in their neighbourhood ( $p > 0.05$ ). One possible explanation for this finding might be that children were equally as likely to be attending extra-curricular activities within the neighbourhood as outside the neighbourhood. Another possibility is that children removed their devices while participating in some after-

school activities (e.g. contact sports, water-based activities). Assuming that this non-wear period was greater than 60 minutes, this data would have been subsequently excluded from the analysis during data processing. More in-depth research in this area that gathers more detail on children's extra-curricular activities and includes measures of a wider range of both individual and social variables may yield greater understanding of this association.

This research also investigated the effect of the school environment on children's physical activity. Commensurate with previous research, schools were locations where students engaged in high levels of MVPA (Beighle et al., 2012; Cox et al., 2006). This finding has implications for research into children's neighbourhood environment as children who attend a school within their neighbourhood displayed both increased time in their neighbourhood and also higher average activity in the neighbourhood. As a mediator of children's neighbourhood activity, this variable could potentially act as a confound in research into the associations between the neighbourhood environment and health related behaviours. The presence of a child's school in their neighbourhood is a variable that much previous research has not adequately accounted for.

## **6.2 Future research directions**

Several questions are raised by the findings of the current project that should be investigated in future research. Firstly, although this study adds to the existing research showing that exposure to greenspace is associated with increased physical activity and emotional wellbeing in children, there is presently no research investigating the factors that influence children's greenspace exposure. A study investigating the individual, environmental, and social factors that might be associated with children's greenspace

exposure would give valuable information that would be useful for understanding and potentially influencing some important health behaviours.

A further question raised by this study is the nature of the association between greenspace exposure and emotional wellbeing. Although a significant association was found between these variables, the single observation methodology employed in this research precludes any ability to infer causation or to detect the direction of any causation in the relationship. It seems plausible both that time in greenspaces causes an increase in children's emotional wellbeing, and that children with higher levels of emotional wellbeing are more likely to seek out natural environments. A longer term observational study, or an intervention study, may enable us to further investigate the nature of this association.

Finally, this study further highlights the need for researchers in this field to develop standardised methods for collecting, processing, analysing, and reporting GPS and accelerometer data. The lack of established guidelines and 'best practice' research methods in this relatively new field has been recognised in previous reviews (Kerr et al., 2011). The resulting methodological inconsistency severely limits the ability to compare findings between studies. Over the last few years there have been efforts by researchers to define best practice for both GPS and accelerometer data (Kerr et al., 2011; Matthews, Hagströmer, Poer, & Bowles, 2012). This represents significant progress towards enabling greater levels of standardisation between studies, however, the combination of GPS and accelerometer data provides additional levels of complexity for data collection, processing, and analysis for which no best practice protocols have been established (Oliver et al., 2010). The promise of these emerging technologies in health and activity research cannot be fully realised until standardised

data collection and handling guidelines are established and adopted by the academic community.

### **6.3. Strengths and limitations**

**6.3.1 Measurements.** The use of GPS and accelerometer devices to provide accurate, objective, high-resolution locational and activity data is a notable strength of the current research, providing a degree of confidence in the validity and reliability of the findings. GPS and accelerometer measures remove the potential for recall bias and have been shown to provide significantly more accurate data than the self-report measures employed in much of the previous research (Badland, Duncan, Oliver, Duncan, & Mavoa, 2010; Duncan, & Mummery, 2007; Prince et al., 2008). This study also used data collection and processing methods previously described in the literature with the aim to closely replicate what could be considered current optimal practice in child activity research (Hinckson et al., 2014; Kerr et al., 2011, Oliver et al., 2011). This study also employed objective measures of cognitive development and risk-taking which have strong evidence for their validity and reliability. This allows a more direct measure of the variables under examination and removes potential confounders and biases from the data collected.

Where objective measures were not possible, the study utilised self-report measures that have shown good levels of reliability and validity in previous studies on children on the same age. Key amongst these are the wellbeing questionnaires that were used which have been thoroughly investigated in large samples of similarly aged school children (Rees et al., 2010). This is also the case for the sensation-seeking scale which, although not as well scrutinized as the wellbeing measures, has also been subject to validity and reliability testing (Stephenson et al., 2003).

The greenspace analysis was limited by the resolution of the available the GIS data for Auckland. The ‘parks’ dataset for the Auckland region available through Open Street Map ([www.openstreetmap.org](http://www.openstreetmap.org)) allowed the identification of time points located within publically accessible parks, sports fields, and reserves. However, this dataset does not contain information on other land areas that would also be categorised as greenspace such as accessible vacant land or school playgrounds. It also lacked the resolution to be able to categorise backyards as greenspaces as has been done in other research (Wheeler, 2010). This dataset was chosen due to a lack of a more comprehensive resource covering the Auckland region.

Inconsistencies between the participating schools in the environments in which the computerised testing took place were a weakness of this study. In School 1, testing took place on laptops in a corner of the library. Although steps were taken to isolate participants from the general library environment this was difficult to achieve. Consequently, students at this school performed their cognitive testing in a sometimes distracting environment. Conversely, at both other schools, cognitive testing took place in a quiet computer lab without any non-participating students present and with less background noise. In particular, at School 2, the student’s classroom teacher was present resulting in a noticeably higher levels of student focus. For such a sensitive measure in which participants are performing cognitively challenging tests under time pressure, the lack of a consistent test environment between schools is a weakness of the study. As reported in Section 6.1, the CNS-VS dataset also showed what seemed like high levels of incomplete data. Of the total number of domain scores calculated from all participants, 8% of the results were invalid. This was largely caused by participant’s incorrect performance of the specific tests (e.g. pressing the wrong

computer key). There is no available data on what constitutes an acceptable level of data completeness for CNS-VS in this age group, however it seems likely that more time given to explaining test instructions by the researcher or closer supervision of students during testing might have yielded more complete results. Upon analysis the CNS-VS measure did not yield any significant associations with any other variables, it is possible that greater supervision, less time-pressure, and a more consistent testing environment would have yielded a different result.

**6.3.2 Sample size.** A further limitation of this study was the relatively small number of participants. As outlined in Section 3.1, statistical power analysis indicated that a sample population of 84 individuals was required in order to detect moderate correlations between greenspace exposure and other variables. Although informed consent was received from 126 students, this study only managed to gather activity and geolocational data from 108 and 72 participants, respectively. There were three key reasons for this low rate of follow-through:

- 1) At all participating schools there was some participant loss through absenteeism, i.e., some students who had consented for the study but who were absent from school on the initial day of testing and device fitting. This resulted in a loss of eight participants from the original 126 who consented.

- 2) The relatively low level of GPS data collected was mostly due to limited availability of GPS receivers for the study. GPS receivers and accelerometers were obtained from AUT's Human Potential Centre for this research project. Although the numbers of accelerometers were more than sufficient for the study's purposes, the limited numbers of GPS receivers affected how many participants could provide locational data in each school. In the end GPS data was collected from 78 participants and six of these data



sets were excluded from the analysis due to insufficient data. Thus the study failed to glean locational data for the number of participants that the power analysis indicated would be necessary for the analysis of greenspace exposure. Despite this, several of the locational analyses conducted in this study did reach significance at the  $p < 0.05$  level. However, the analysis would have been stronger and a greater number of significant associations might have been detected had more GPS data been collected.

3) For both the accelerometer and GPS data, several datasets were excluded from the analysis due to insufficient data. As outlined in section 3.5.1, six of the merged GPS-accelerometer files and a further four of the unmatched accelerometer files failed to meet inclusion criteria. Data exclusion for the combined GPS-Accelerometer data followed the criterion established by Almanza (2012). This resulted in exclusion of six combined location and activity files, or 7.7% of the data collected. These figures seem commensurate with those reported by similar studies; however, the wide range in exclusion criteria employed amongst different studies makes direct comparison impossible. Almanza (2011) reported data exclusion rates of 16.3% using the same criteria as the current study, whereas Cooper et al (2010) reported insufficient data in 5.5% of participants using less stringent criteria. As mentioned in Section 6.2, there are currently no recognised guidelines for ‘best practice’ in defining inclusion criteria. Other studies have used much less stringent criteria such as including all days of data with > 1 minute of combined GPS and accelerometer data (Lachowycz et al., 2012). Adoption of more lenient inclusion criteria would have resulted in a larger final sample size and it is currently unknown how the inclusion of these additional, less-complete datasets may have affected the validity of the results. The study’s data

exclusion rate of 8.5% for the accelerometer data seems comparable to those reported in the existing literature. It is noteworthy that many studies in this field have not reported their proportion of excluded data, but in cases where it has been reported, the amount of insufficient data has been given as 5% (Sharpe et al., 2011), 5.6% (Tudor-Locke et al., 2015), and 19.9% (Riddoch et al., 2004).

**6.3.3 Sample bias.** Another weakness of this study is the potential for sampling bias, which may have inadvertently affected the results due to non-representative selection of participating schools and individual self-selection to be involved in the study. As noted in section 3.1, schools were approached by the researcher and invited to participate in the study. Although schools in areas representing a wide spectrum of socioeconomic statuses were approached, the three schools that finally agreed to be involved in the research were located in middle to high decile neighbourhoods. Several approaches to low-decile schools were made but these were unsuccessful. It follows that the students included in the study may not be completely representative of the total population and this limits the generalisability of the results. In addition to this, although all students in the appropriate academic years were invited to participate in the research, the students and their parents were able to select whether they would be involved or not. While this was appropriate and necessary to ensure ethical and respectful conduct of the research, it creates the possibility that the students who declined the offer to participate differed in some way from those who elected to be involved. A more comprehensive analysis might have included a random sample of non-participating students to see if there were any significant differences between them and the study population, however this lay outside the scope of the current study.

## **6.4 Conclusion**

This study adds to our knowledge of the importance of greenspaces in enhancing healthy childhood development. It joins the growing body of evidence that has associated exposure to greenspaces with increased levels of MVPA in children. The study also provides evidence that children's time in greenspace is positively associated with emotional wellbeing. A novel aspect of this research is the ability to isolate the associations of both greenspace exposure and physical activity on children's emotional wellbeing. This study found that although both greenspace exposure and time in MVPA were independently related to children's reported life satisfaction, the strength of this association was stronger for greenspace exposure. The neighbourhood analysis investigated the associations between the time that children spend in their neighbourhood environment and several individual and neighbourhood level variables. Generally this analysis failed to identify any significant associations; however, it was found that low levels of time in the neighbourhood were generally associated with low levels of MVPA. Despite the limitations around sample size and potential for sampling bias, this research has added to the existing body of literature and further enhances our knowledge of factors that promote children's physical activity and emotional wellbeing.

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## Appendix 1

### Letter to the Board of Trustees at prospective schools.



To: The Chairperson of the Board of Trustees

I am a student at AUT University working towards my Masters degree in Health Science. I'm conducting a research project investigating children's physical activity levels and the amount of time that they spend outdoors.

Research shows that children who get outdoors more and are more physically active learn better, develop healthier attitudes towards risk taking, have higher levels of emotional wellbeing, and have better physical health. However we also know that today's children are spending more times indoors and are more sedentary than ever before and there is widespread concern about the long term effects that this might have on their healthy development.

My research is investigating physical activity levels in intermediate age pupils in the Auckland area. The aim of the research is to investigate the amount of physical activity children of this age engage in during a typical week and where that activity takes place. We are especially interested in how much of that activity takes place in green spaces (parks, reserves etc.). We will also be looking at how this activity might relate to children's emotional wellness, cognitive development and the way that they assess risks. The research will give us insight into some of the factors that might contribute to children's development and wellbeing.

I am writing to ask if your school would be interested in being part of this research project.

There will be two components to this research:

1. Students who volunteer to participate in the research will be run through a series of tests including computer-based tests of their cognitive development, and propensity to take risks. They will also be asked to fill out a questionnaire on their normal activity patterns and emotional wellness. A gender-matched research assistant will take basic measurements of the student's height, weight

and waist circumference. These tests will take about an hour of the student's time.

2. These students will be given a belt with a GPS and accelerometer device attached and asked to wear this as much as possible over the following week. These devices will automatically record the student's location and activity level.

This research will involve taking students out of class in order to conduct the testing and will require an appropriate space and access to the schools computers for the online testing component. I am very conscious of not wanting to disrupt the school's normal routine in any avoidable way and I'm happy to work in with staff in order to minimise any potential inconvenience.

This project has been reviewed and approved by the AUT Ethics Committee.

If you have any further questions I would be more than happy to answer them.

Yours Sincerely,

A handwritten signature in black ink, appearing to read 'Jonathan Ward', is centered on a light blue rectangular background.

Jonathan Ward

BHSc, PgDipHSc

## Appendix 2

### Parent/Guardian information and consent form.

# Parent / Legal Guardian Information Sheet



#### **Project Title**

Physical activity and childhood wellness in New Zealand youth.

#### **An Invitation**

My name is Jonathan Ward. I am a student at AUT University in Auckland working towards my Masters Degree in Health Science. I am researching the links between children's physical activity levels and their mental and emotional development and I would like to invite your child to be part of this research. Participation is voluntary and participants may withdraw at any time prior to or during the workshop. This research will contribute to my Masters thesis.

#### **What is the purpose of this research?**

The purpose of the research is to investigate the amount of physical activity children in Auckland engage in during a typical week and where that activity takes place. We will also be looking at how this activity might relate to children's emotional wellness, cognitive development and the way that they assess risks. The research will give us insight into some of the factors that might contribute to children's growth and wellbeing.

#### **How was my child invited to participate in this research?**

Your child's school has offered to participate in this research project. All children in Class 6 and 7 are being given the opportunity to participate.

#### **What will happen in this research?**

On the 10<sup>th</sup> of November your child will be taken out of class for about an hour to complete the testing. They will have to fill out a questionnaire and they will also participate in some computerised tests on the school computers. The questionnaire will ask them about their overall satisfaction with different aspects of their lives, the way that they spend their time during the week and weekends, and general questions about their perceptions of their family life. These questions are all ones that are commonly

used in surveys of children's emotional wellness in New Zealand and overseas. A researcher of the same gender as your child will also take basic body measurements including your child's height, weight and waist measurement. Their responses and measurements will be kept completely confidential. They will not at any time be asked to share any of their answers with their peers.

The child will then be given a GPS (global positioning system) receiver and an accelerometer which are small portable devices that are worn on a waist belt. The child will be asked to wear this belt for a week except when sleeping, swimming or bathing. These devices will record the child's location and the intensity of their movement at intervals over the course of the week. These devices are purely recorders they do not transmit any information. The reason we would like to monitor your child's location is so that we know where they are being active (eg. indoors, parks etc). During this week the students will also be asked to keep a basic written record of the places they visit. I will collect the devices off the children from school after a week's time (Mon 17th).

**What are the discomforts and risks?**

It is not anticipated that participants will encounter any greater risk than that of a normal school day. The children will be asked to continue with their normal weekly activities.

**What are the benefits?**

By participating in this study children will have the opportunity to contribute to our understanding of factors that contribute to healthy physical, mental, and emotional growth in childhood.

**How will privacy be protected?**

Due to the nature of the study, some teachers and peers might know that your child is involved in the study. All your child's data will be kept completely confidential and no identifying information will be available to anyone apart from myself. In published reports, I will not include information that will make it possible to identify any participant. Research records will be kept in a locked file and will not include names or other personally identifying information. In accordance with standard research practice data will be stored for ten years and permanently destroyed afterwards. Participants contact information is only available to me and kept on a password protected device.

**What are the costs of participating in this research?**

Their participation will not result in any financial costs.

**How do I agree to participate in this research?**

If you would like your child to be involved in this research please sign the consent form attached to this sheet and your child will bring it back to his/her classroom teacher. Participants need to confirm by **Friday 24<sup>th</sup> Oct 2014**

**Will I receive feedback on the results of this research?**

You are welcome to receive a summary of the research results. If you would like to receive this please indicate on the consent form and fill in your address. We will mail a research summary out to you when the project is completed. This will be towards the end of next year.

**What do I do if I have concerns about this research?**

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor Dr Scott Duncan, [scduncan@aut.ac.nz](mailto:scduncan@aut.ac.nz), 921 9999 ext 7678. Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEK, Kate O'Connor, [ethics@aut.ac.nz](mailto:ethics@aut.ac.nz), 921 9999 ext 6038.

**If you'd like any more information about this research please be in touch.**

***Researcher Contact Details:***

Jonathan Ward; [jonathan@elementsphysio.co.nz](mailto:jonathan@elementsphysio.co.nz); 021 484 087

***Project Supervisor Contact Details:***

Dr Scott Duncan, [scduncan@aut.ac.nz](mailto:scduncan@aut.ac.nz), 921 9999 ext 7678

**Approved by the Auckland University of Technology Ethics Committee on 12<sup>th</sup> May 2014, AUTEK Reference number 14/61.**

# Parent/Guardian Consent Form



***Project title:*** Physical activity and Childhood Wellness in New Zealand youth.

***Project Supervisor:*** Dr Scott Duncan

***Researcher:*** Jonathan Ward

**If you'd like your child to participate in this research please read and sign this form and return it to your child's classroom teacher by Friday 24<sup>th</sup> Oct**

- ☐ I have read and understood the information provided about this research project in the Information Sheet
- ☐ I have had an opportunity to ask questions and to have them answered.
- ☐ I understand that I may withdraw my child/children at any time prior to completion of data collection, without being disadvantaged in any way.
- ☐ If my child/children withdraw, I understand that all data collected from my child/children will be destroyed.
- ☐ I agree to my child/children taking part in this research.
- ☐ I wish to receive a copy of the report from the research once it's completed (please tick one):

Yes ☐ No ☐

Child/children's name/s : .....

Parent/Guardian's signature: .....

Parent/Guardian's name: .....

Parent/Guardian's Contact Details (if you would like to receive a research report):

.....  
.....  
.....  
.....

Date:

***Approved by the Auckland University of Technology Ethics Committee on 12<sup>th</sup> May 2014. AUTEK Reference number 14/61***

# Student Information Sheet



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**Project Title: Physical activity and Childhood Wellness in New Zealand youth**

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## **An Invitation**

Our names are Scott Duncan and Jonathan Ward. We are researchers at AUT University in Auckland. We are trying to find out how physically active people your age are and we're also interested in how much time people your age spend in different environments (such as at school, at home, or in parks). We're interested in how these different factors might affect your mental, emotional and physical wellness.

## **What will happen in this study?**

We will be doing this research in your school from Monday 10<sup>th</sup> Nov until Monday 17<sup>th</sup> Nov. If you agree to be part of this study we will ask you to fill out some questionnaires and do some tests on the school computers. This testing will probably take about an hour during school time. Also at this time we'll record your height and weight and measure around your waist. Your test results and body measurements will all be kept private, no one else will see them.

After that we'll give you a belt with two different devices on it. One is a small GPS receiver which will automatically keep a track of all the places you go. The other device is an accelerometer which will record how active you are. We'd like you to wear this pretty much all the time for 7 days (including after school and the weekend). You can take the devices off when you're sleeping, or if you're bathing or swimming, but otherwise we'd like you to wear it as much as possible. One of the devices (the GPS) will need to be charged overnight.

Over this 7 days we'll also give you a simple diary to keep- all we want you to do is record the places where you spend time each day and how you travel between these

places (car, bus, walking, scootering etc). After 7 days I'll come back and pick up the devices.

**How was I chosen?**

Your school has agreed to be part of this study and we're also asking students from other schools around Auckland to be involved. Please read this form with your parent or caregiver and ask any questions you may have before signing your name. You or your parents are welcome to ask me any questions about this project- my details are on this form

**How do I agree to be part of this study?**

Please sign the consent form, and ask a parent or caregiver to sign as well. You will need to give all forms to your teacher by **Fri 24<sup>th</sup> October**.

**Can I change my mind?**

Yes, you can stop being part of the study at any time.

**What will happen if I don't want to take part?**

Nothing will happen. This is totally optional and the decision of you and your parents/caregivers.

**How will my privacy be protected?**

Other people may know that you are involved in the study but we won't share your information with anyone. All the information you give us will be kept private. When we write up the results of this study we won't use your name or put in any information that will identify you. All the information we collect will be kept safely in a locked cabinet or on a computer that is protected by a password. We will keep the information for 10 years and after that we'll destroy it.

**Who do I talk to if I want to know more?**

Ask your parent/legal guardian to contact us with your questions and we will be happy to answer.

**Our contact details are:**



Jonathan Ward  
102 Main Highway  
Ellerslie

Ph 021 484 087

E-mail: [jonathan@elementsphysio.co.nz](mailto:jonathan@elementsphysio.co.nz)

Dr Scott Duncan

Human Potential Centre

AUT University

Ph: 921 9999 ext 7678

Fax: 921 9746

E-mail: [scott.duncan@aut.ac.nz](mailto:scott.duncan@aut.ac.nz)

**Who should my parents/legal guardian contact if they have any concerns?**

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Scott Duncan, [scott.duncan@aut.ac.nz](mailto:scott.duncan@aut.ac.nz), 921 9999 ext 7678.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTC, Kate O'Connor, [ethics@aut.ac.nz](mailto:ethics@aut.ac.nz), 921 9999 ext 6038.

# Student Assent Form

## How do I agree to be part of this study?

All you need to do is sign this form, and ask your parent/legal guardian to sign their form. Then return this to your classroom teacher by date

\_\_\_\_\_

## Can I change my mind?

Yes, you can stop being part of the study at any time

## What will happen if I don't want to take part?

Nothing will happen. No one will know if you decide not to take part.

## Who do I talk to if I want to know more?

Ask your parent/legal guardian to contact us (see contact details below) with your questions and we will be happy to answer them.

- ☐ I have read through this form with a parent/legal guardian.
- ☐ I have had an opportunity to ask questions and to have them answered.
- ☐ I understand that I may decide to stop being part of the study at any time.
- ☐ I understand that my data may be retained by AUT for comparative purposes.
- ☐ I agree to be part of this study.

Your Name: .....

Room number: .....

Year Level: .....

Date of Birth: .....

## Our contact details:

Jonathan Ward

Ph: 021 484 087

E-mail: jonathan@elementsphysio.co.nz

Dr Scott Duncan  
Human Potential Centre  
AUT University  
Ph: 921 9999 ext 7678  
Fax: 921 9746  
E-mail: [scott.duncan@aut.ac.nz](mailto:scott.duncan@aut.ac.nz)

## Appendix 3

### Activity and Wellbeing Questionnaire



**HUMAN POTENTIAL CENTRE**  
AN AUT UNIVERSITY RESEARCH CENTRE



### Activity and Wellbeing Questionnaire

#### *Home address:*

Please write your home address on the lines below.

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Directions: We would like to know what thoughts about life you have had during the past several weeks. Think about how you spend each day and night and then think about how your life has been during most of this time. Here are some questions that ask you to indicate your satisfaction with your overall life. Circle the words next to each statement that indicate the extent to which you agree or disagree with each statement. It is important to know what you REALLY think, so please answer the questions the way you really think, not how you should think. This is NOT a test. There are NO right or wrong answers.

#### *Satisfaction with Life*

##### **1. My life is going well.**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

##### **2. My life is just right**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

**3. I wish I had a different kind of life**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

**4. I have a good life**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

**5. I have what I want in life**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

**6. When you think about your life how happy are you with your life as a whole?** (please circle the number from 0 to 10 that best indicates your happiness with life as a whole)

0	1	2	3	4	5	6	7	8	9	10
Very Unhappy										Very Happy

***Satisfaction with different aspects of your life***

In this section we will ask you questions about how happy you are with different parts of your life. Please circle the number that best indicates your happiness level from 0 (very unhappy) to 10 (very happy).

**7. How happy are you with your family?**

0	1	2	3	4	5	6	7	8	9	10
Very Unhappy										Very Happy

**8. How happy are you with your friends?**

0	1	2	3	4	5	6	7	8	9	10
Very Unhappy										Very Happy

**9. How happy are you with your health?**

0	1	2	3	4	5	6	7	8	9	10
Very Unhappy										Very Happy

**10. How happy are you with your appearance (the way that you look)?**

0	1	2	3	4	5	6	7	8	9	10
Very										Very
Unhappy										Happy

**11. How happy are you with the way you use your time?**

0	1	2	3	4	5	6	7	8	9	10
Very										Very
Unhappy										Happy

**12. How happy are you about what may happen to you later in life?**

0	1	2	3	4	5	6	7	8	9	10
Very										Very
Unhappy										Happy

**13. How happy are you about the home you live in?**

0	1	2	3	4	5	6	7	8	9	10
Very										Very
Unhappy										Happy

**14. How happy are you about the things you have (like money and the things you own)?**

0	1	2	3	4	5	6	7	8	9	10
Very										Very
Unhappy										Happy

**15. How happy are you about the school, in general?**

0	1	2	3	4	5	6	7	8	9	10
Very										Very
Unhappy										Happy

**16. How happy are you about the amount of choice you have in life?**

0	1	2	3	4	5	6	7	8	9	10
Very										Very
Unhappy										Happy

## *Sensation seeking*

This section asks four questions about the sorts of things you like doing on a regular basis. Circle the answer that fits you best.

### **17. I would like to explore strange places**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

### **18. I like to do frightening things**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

### **19. I like new and exciting experiences, even if I have to break the rules**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

### **20. I prefer friends who are exciting and unpredictable.**

0	1	2	3	4
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

## ***Normal School Day Activities:***

Please indicate how much time on a typical <u>school day</u> you do the following activities. Please think about the time from when you wake up until you go to bed. Please <b>DO NOT</b> include time when you are in school during regular hours. Do not include weekends.							
	None	15 min per day	30 min per day	1 hour per day	2 hours per day	3 hours per day	4 or more hours per day
21. Watching television/videos/DVDs	0	1	2	3	4	5	6
22. Playing computer or video games (like Nintendo or Xbox)	0	1	2	3	4	5	6
23. Using the internet, emailing or other electronic devices.	0	1	2	3	4	5	6
	None	15 min per day	30 min per day	1 hour per day	2 hours per day	3 hours per day	4 or more hours per day
24. Doing homework (including reading, writing or using the computer)	0	1	2	3	4	5	6



25. Reading a book or magazine NOT for school (including comic books)	0	1	2	3	4	5	6
26. Riding in a car, bus, etc.	0	1	2	3	4	5	6
27. Playing outside (not in an organised sport)	0	1	2	3	4	5	6
28. Playing a an outside sport (such as soccer, netball or running)	0	1	2	3	4	5	6
29. Doing indoor sport or physical activity (such as dance,	0	1	2	3	4	5	6

### ***Normal Weekend activities***

Please indicate how much time on a typical <u>weekend day</u> you do the following activities. Please think about the time from when you wake up until you go to bed. Do not include weekdays.							
	None	15 min per day	30 min per day	1 hour per day	2 hours per day	3 hours per day	4 or more hours per day
30. Watching television/videos/DVDs	0	1	2	3	4	5	6
31. Playing computer or video games (like Nintendo or Xbox)	0	1	2	3	4	5	6
32. Using the internet, emailing or other electronic media	0	1	2	3	4	5	6
33. Doing homework (including reading, writing or using the computer)	0	1	2	3	4	5	6
34. Reading a book or magazine NOT for school (including comic books)	0	1	2	3	4	5	6
35. Riding in a car, bus, etc.	0	1	2	3	4	5	6
36. Playing outside	0	1	2	3	4	5	6
37. Playing a an outside sport (such as soccer, netball or running)	0	1	2	3	4	5	6
38. Doing indoor sport or physical activity (such as dance,	0	1	2	3	4	5	6

### ***Sleep and Wake times:***

**39. On school days I usually wake up at \_\_\_\_\_ AM**

**40. On school days I usually go to bed at \_\_\_\_\_ PM**

**41. On Saturdays I usually wake up at \_\_\_\_\_ AM**

**42. On Saturdays I usually go to bed at \_\_\_\_\_ PM**

**43. On Sundays I usually wake up at \_\_\_\_\_ AM**

***Family togetherness:***

	Mostly true	Mostly false	Don't know
44. Family members really help and support one another	1	2	3
45. We often seem to be killing time at home	1	2	3
46. We put a lot of energy into what we do at home	1	2	3
47. There is a feeling of togetherness in our family	1	2	3
48. We rarely volunteer when something has to be done at home	1	2	3
49. Family members really back each other up	1	2	3
50. There is little group spirit in our family	1	2	3
51. We get along really well with each other	1	2	3
52. There is little time and attention for everyone in our family	1	2	3

## Appendix 4

### Accelerometer and GPS device information sheet



## RESEARCH PROJECT

### INFO SHEET

### ENVIRONMENT AND ACTIVITY STUDY

Dear Student,

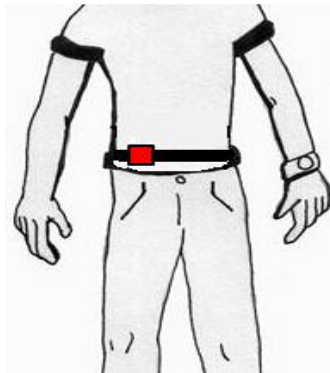
Thanks for taking part in this study. We are very grateful for your involvement.

This sheet contains information on the two devices that you will be wearing over the next week, please read it carefully and ask your parents/caregivers to do the same. If you have any questions you or your parents can get in touch with me at [jonathan@elementsphysio.co.nz](mailto:jonathan@elementsphysio.co.nz) or 021 484 087.

#### **Accelerometer:**

This small red activity meter records general movement and allows us to get a better idea of your overall activity level. We will **not** be able to tell what kind of specific activity is happening. At first, the belt may feel slightly awkward, but after a few hours, you will probably get used to it and not notice it as much. It is **extremely** important for our study that you wear the meter properly. Please follow these instructions carefully:

- Wear the meter attached to the belt around your waist, just above your **right** hipbone. You can wear it either underneath or on top of your clothing.



- Wear the meter **snug** against your body. If you have to, you can adjust the belt by pulling the end of the strap to make it tighter. Or, to loosen the belt, push more of the strap through the loop. **Wear the belt tight enough so that the meter does not move when you are being active.**
- Please **put it on first thing in the morning** - either just after you get out of bed or just after you shower or take a bath in the morning.
- **Do not submerge the meter in water** (swimming, bathing, etc.)

- Keep the activity meter on all day (unless swimming or in the water).
- At night, **take it off right before you go to bed. You should be wearing the meter for *at least 12 hours each day*.** You do not need to charge this device or do anything to it except wear it.
- Do not let anyone else wear it.

### **GPS receiver:**

The slightly larger black device you're wearing is a GPS receiver. This will automatically record your location at set intervals during the week. The GPS unit will be worn inside a small pouch on the same elastic waist belt as the accelerometer. We've taped the unit into the pouch for safety. We've also put tape over the control switch because there's no need for you to change this during the week.

- Wear the GPS receiver on the left side of the belt we've provided. You can wear it on top of your clothing or underneath your clothing if you'd prefer.
- Due to the battery life of GPS receivers, **you will need to charge the receiver each night before you go to sleep.** This is done by plugging the device into a wall socket with the charger provided.

Key points for you to remember are:

- Wear both devices during the day when you are awake.
- Remove them when showering, bathing, or swimming.
- Charge the GPS receiver each night when you go to sleep.
- You may remove the devices at any time if you experience any discomfort. But please try and wear them for at least 12 hours each day.

If you have any questions about the equipment please do not hesitate to contact me.

Once again thank you for being part of this research.

Regards,



Jonathan Ward  
[jonathan@elementsphysio.co.nz](mailto:jonathan@elementsphysio.co.nz)  
021 484 087

- This table is for you to record the times when you wear and remove the GPS and Accelerometer devices. Please try to complete the table daily, rather than from memory at the end of the week.
- Remember to charge the GPS unit every night.
- Please return this form along with the devices, belt, and charger on Tues 23<sup>rd</sup> Sept

### Wear time diary: ENVIRONMENT AND ACTIVITY STUDY

ID:	e.g.	Day 1: Monday 15 <sup>th</sup> Sept	Day 2: Tuesday 16 <sup>th</sup> Sept	Day 3: Wednesday 17 <sup>th</sup> Sept	Day 4: Thursday 18 <sup>th</sup> Sept	Day 5: Friday 19 <sup>th</sup> Sept	Day 6: Saturday 20 <sup>th</sup> Sept	Day 7: Sunday 21 <sup>st</sup> Sept	Day 8: Monday 22 <sup>nd</sup> Sept	Day 9: Tuesday 23 <sup>rd</sup> Sept
1. What time did you <b>wake up</b> ?	0700									
2. What time did you <b>attach the belt with the accelerometer and GPS</b> ?	0700									
3. What time did you <b>remove the devices</b> ?	2130									<b>Return forms today</b>
4. What time did you <b>go to bed</b> ?	2130									
5. What other times during the day was the <b>accelerometer not worn</b> ?	1100-1130									
6. What were you doing when you were not wearing the accelerometer	Swimming									

## Appendix 5

### Daily activity diary



## RESEARCH PROJECT

### ACTIVITY RECORD:

### ENVIRONMENT AND ACTIVITY STUDY

Date	Places you went to	Address	How did you travel to and from these places?
Example	1.School 2. Friend's house 3. Home after friends place 4. Swimming	1. 55 Amy St; Ellerslie 2. 123 Address St 3. 45 Home Tce 4. Glen Innes pools	1. Car 2. Walked with friend after school 3. Car 4. Bike
Monday 10 <sup>th</sup> Nov			
Tues 11 <sup>th</sup> Nov			
Wed 12 <sup>th</sup> Nov			

Thurs 13 <sup>th</sup> Nov			
Fri 14 <sup>th</sup> Nov			
Sat 15 <sup>th</sup> Nov			
Sun 16 <sup>th</sup> Nov			
Mon 17 <sup>th</sup> Nov			