Transport to School Habits, Physical Activity and Weight Status in Adolescents

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ABSTRACT

Background: Active transport (AT) to school is a means for adolescents to increase the amount of daily moderate-to-vigorous physical activity (MVPA) and can help them achieve physical activity (PA) guidelines. This study compared PA in adolescents using AT only (n=73), motorised transport (MT) only (n=185) or active and motorised transport (AT+MT) (n=56) to school and examined the association of adolescents' transport modes to school, MVPA and weight status.

Methods: Adolescents (n=314; age: 14.7±1.4 years; 67.2% female) from twelve Dunedin secondary schools completed the online BEATS Student Survey and reported sociodemographic characteristics and transport to school habits. Height and weight were measured. MVPA was objectively-measured using 7-day accelerometry.

Results: Compared to MT only, higher proportions of adolescents in AT only and AT+MT met PA guidelines (AT only: 47.9%; AT+MT: 46.4%; MT only: 33.5%, $p=0.048$). Compared to MT only, AT only accumulated more MVPA daily (AT only: 61.2±23.2; MT only: 52.5±19.6 min, $p=0.004$) and during an average school day (AT only: 65.3±22.4; MT only: 54.4±19.1 min, $p<0.001$) but not on an average weekend day (AT only: 50.9±36.2; MT only: 46.8±33.7 min, $p= 0.679$). Compared to MT only, AT only and AT+MT accumulated more MVPA an hour before school (8am-9am) (AT only: 12.7±7.5; AT+MT: 9.8±6.7; MT only: 5.6±4.3 min; $p<0.001$) and after school (3pm-4pm) (AT only: 13.3±6.4; AT+MT: 9.9±5.3; MT only: 8.4±5.1 min; $p<0.001$), but not late after school (4pm-8pm) (AT only: 14.2±9.5; AT+MT: 16.7±11.9; MT only: 14.8±10.1 min; $p=0.377$). No significant associations were observed between weekly, school day and weekend day MVPA (all $p>0.05$), weight status and transport modes to school in adolescents.

Conclusions: Adolescents using AT only and AT+MT to school accumulated more MVPA during school commute times compared to MT only, contributing to their higher overall PA levels. AT+MT to school is also a plausible way to increase PA in adolescents when AT only is not feasible due to distance to school.

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PREFACE

This Master's research topic "Transport to School Habits, Physical Activity and Weight Status in Adolescents" was originally stemmed from my passion as a Physical Education teacher in Singapore. As a Physical Education teacher, I am very keen to acquire more knowledge on areas relating to physical activity, obesity and sedentary lifestyles in children and adolescents so as to utilise these knowledge into my teaching profession.

My research question was formulated together with my supervisor, Associate Professor Sandra Mandic at the School of Physical Education, Sport and Exercise Sciences, University of Otago. Dunedin, New Zealand. Associate Professor Sandra Mandic was the Principal Investigator of the Built Environment and Active Transport to School (BEATS) Study that was conducted in Dunedin, New Zealand from 2013 - 2017, which examined the interaction between transport choices, built environment, physical activity levels, weight status in adolescents using an ecological approach. The BEATS Study was a large scale and comprehensive research study that consisted of six different sub-projects involving students, parents, teachers and principals.

Data used in this thesis was obtained from the BEATS Student Survey which was conducted between 2014 - 2015. Although I was not involved in the BEATS Student Survey data collection, I had the opportunity to be involved in the BEATS Parental Survey in 2016 and 2017. In the process of this research, I was involved in accelerometer data collection (set-up, delivery, downloading data, processing wear time) for a different sub-study within the overall BEATS Study (for 80+ parental accelerometer assessments) and performed practice data analysis on dozen of accelerometer files to familiarise myself with the data analysis procedure. All these experiences have provided invaluable learning and knowledge on the research study that I have undertaken in this thesis.

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LIST OF ABBREVIATIONS

PA	Physical Activity
AT	Active Transport
MT	Motorised Transport
AT+MT	Active and Motorised Transport
MVPA	Moderate-to-Vigorous Physical Activity

CHAPTER 1

1 Introduction

Regular physical activity (PA) provides numerous health benefits in adolescents such as improved cardiorespiratory and musculoskeletal fitness, lower levels of adiposity and improved mental health (Janssen & Leblanc, 2010; Kjonniksen, Torsheim, & Wold, 2008; Warburton, Nicol, & Bredin, 2006). Despite the importance of regular PA, adolescents' PA levels have declined significantly in the recent decades (Salmon & Timperio, 2007) due to a combination of personal, environmental and societal factors (Pratt, Stevens, & Daniels, 2008). Increasing number of adolescents engaging in inactive lifestyles (Schofield, Mummery, & Schofield, 2005) also poses a major concern in the long term as adolescents who are engaged in a variety of PA regularly have more opportunities to establish lifelong PA habits (Kjonniksen et al., 2008; Strong et al., 2005). Declines in adolescents' PA were found to coincide with age-related transition from childhood to adolescence (Dumith, Gigante, Domingues, & Kohl III, 2011; Olds, Maher, & Ridley, 2011; Riddoch et al., 2004; Troiano et al., 2008; Trost et al., 2002) as well as academic progression from primary to secondary school (Larouche, Faulkner, & Tremblay, 2013), which have contributed to rising levels of overweight and obesity in adolescents (Lobstein, Baur, & Uauy, 2004), resulting in negative long-term implications for health.

Obesity is a major health concern worldwide in both developed and developing countries (Lau et al., 2007; Lobstein et al., 2004). In children and adolescents, obesity is measured using standardised age- and gender-specific cut-points of the body mass index (BMI) (Cole, Bellizzi, Flegal, & Dietz, 2000), which has been commonly used as an indicator of weight status or adiposity in the younger population (Must & Tybor, 2005). Childhood obesity may predispose individuals to obesity in adulthood and increases risk for development of non-communicable diseases such as cardiovascular diseases, cancers, chronic respiratory diseases and diabetes (Adair, 2008; Berenson, 2012; Lobstein et al., 2004; Reilly et al., 2003). In addition, obese children and adolescents experience lower health-related quality of life, increased depression and lower self-esteem compared to their healthy-weight peers (Reilly et al., 2003; Taylor, Forhan, Vigod, McIntyre, & Morrison, 2013). In adolescents, adverse health effects of obesity were found to continue from adolescence to adulthood (Adair, 2008; Reilly et al., 2003).

Rising rates of overweight and obesity in adolescents have been attributed to a reduction in PA and increased sedentary behaviours (Lobstein et al., 2004). Sedentary behaviour alone is positively associated with obesity (Must & Tybor, 2005) and increases risks of chronic diseases and premature mortality in the adult population (Chau et al., 2013; Edwardson et al., 2012; Wilmot et al., 2012). The amount of time spent in sedentary activities such as watching television, using computer and laptops and other activities that involve sitting for long hours contributes to obesity in the younger population (Janssen et al., 2005; Must & Tybor, 2005; Strong et al., 2005). On the other hand, participating in PA prevents excess weight gain in adolescents (Must & Tybor, 2005; Simon et al., 2014) and contributes positively to cardiovascular, musculoskeletal and mental health in this age group (Janssen & Leblanc, 2010; Strong et al., 2005). Therefore, improving modifiable behavioural factors such as increasing PA and/or reducing sedentary activities through adopting physically active lifestyles may be beneficial towards preventing weight gain and alleviating the associated adverse health consequences in adolescents.

Active transport (AT) is a non-motorised form of transport such as walking or cycling (Faulkner, Buliung, Flora, & Fusco, 2009) and represents an important source of PA for adolescents (Carver et al., 2011; Chillón et al., 2010; Duncan, Duncan, & Schofield, 2008; Hohepa, Schofield, Kolt, Scragg, & Garrett, 2008). In many developed countries, including New Zealand, adolescents' transport to school habits have changed over the last few decades with a significant decline in AT to school and an increased reliance on motorised transport (MT) (Dygryn, Mitas, Gaba, Rubin, & Fromel, 2015; Gray et al., 2014; Mandic et al., 2015a; McDonald, 2007; Ministry of Transport, 2015; Reimers, Jekauc, Peterhans, Wagner, & Woll, 2013; van der Ploeg, Merom, Corpuz, & Bauman, 2008). Consequently, declining rates of AT to school have further limited adolescents' PA opportunities which represent an additional challenge to meet their daily required PA levels to achieve optimal health benefits.

Previous studies have found that AT to school in adolescents was associated with higher levels of weekly moderate-to-vigorous physical activity (MVPA) (Chillón et al., 2011; Chillón et al., 2010; Hohepa et al., 2008; Larouche, Faulkner, Fortier, & Tremblay, 2014; Mendoza et al., 2011; Saksvig et al., 2007), school day MVPA (Alexander et al., 2005; Carver et al., 2011) and step counts (Abbott, Macdonald, Nambiar, & Davies, 2009; Duncan et al., 2008; Hohepa et al., 2008) compared to those who used MT to school. Three previous studies (Mendoza et al., 2011; Saksvig et al., 2007; Saksvig et al., 2012) examined objectively measured PA in adolescents during school commute times and found significantly higher levels of MVPA before school (Mendoza et al., 2011; Saksvig et al., 2007; Saksvig et al., 2012) and after school (Mendoza et al., 2011; Saksvig et al., 2012) hours in AT users compared to MT users. Only one previous study that examined PA levels in adolescents who used combined active and motorised transport (AT+MT) to school, in addition to AT only and MT only, reported that adolescents who used AT+MT to school accumulated higher daily energy expenditure compared to MT users (Tudor-Locke, Ainsworth, Adair, & Popkin, 2003). Hence, it is evident that AT to school in adolescents provides a potential source of PA accumulated on a regular basis to increase PA levels in adolescents. At the same time, encouraging AT+MT to school may be a feasible alternative to using solely MT to school, which may increase PA opportunities in adolescents.

Previous studies found positive associations between AT to school, PA and weight status in adolescents (Larouche et al., 2014; Mendoza et al., 2011; Tudor-Locke et al., 2003) whereas others have reported inconclusive evidence pertaining to the association of AT to school and weight status in adolescents (Baig et al., 2009; Landsberg et al., 2008; Mota, Ribeiro, Santos, & Gomes, 2006). Thus, more research is necessary to examine the relationship between PA and weight status in AT users to school.

Therefore, the purpose of this cross-sectional study was to compare PA and weight status in New Zealand adolescents using AT only, MT only and AT+MT to school. The primary aim of this study was to examine the association between adolescents' transport modes to school and PA levels throughout the week, on school days and weekend days as well as during different times of the school day (an hour before school (8 am - 9 am), an hour after school (3 pm - 4 pm) and late after school hours (4 pm - 8 pm)). The secondary aim of this study was to examine the relationship between PA and weight status ("underweight or healthy weight" and "overweight or obese") in adolescents using AT only, MT only and AT+MT to school.

CHAPTER 2

2 Literature Review

2.1 Background

Obesity is a global issue reaching epidemic proportions in both developed and developing countries and affects not only adults but also children and adolescents (Lau et al., 2007). Childhood obesity progresses and follows through into adulthood and increases rates of cardiovascular and other non-communicable diseases (Lobstein et al., 2004). Increasing prevalence of overweight and obesity in young people has been attributed to reduced levels of PA and increased sedentary behaviours (Lobstein et al., 2004). On the other hand, an increase in PA prevents relative weight and fat gains during childhood and adolescence (Must & Tybor, 2005). Compared to moderate intensity PA, a vigorous intensity of PA has greater effect on maintaining as well as reducing weight and body fat in adolescents of both genders (Ramires, Dumith, & Goncalves, 2015).

In adults, regular PA is effective in preventing several chronic diseases and premature deaths (Warburton et al., 2006) and also contributes to better cardiorespiratory and cardiovascular functions, reduced risks of degenerative diseases and mortality, enhanced weight maintenance and improved quality of life (Bouchard & Shepherd, 1994). Therefore, promoting lifestyle changes to increase PA levels improves public health by reducing risks of obesity and other chronic diseases in the general population (Leonard, 2001).

2.2 Overweight and Obesity in Adolescents

Prevalence of overweight and obesity in children and adolescents has reached high levels worldwide in many countries including the United States (Ogden et al., 2016), China (Ji & Chen, 2013), New Zealand (Utter, Denny, Teevale, Peiris-John, & Dyson, 2015) and Portugal (Marques & de Matos, 2016). Among children and adolescents in developed countries, rates of overweight had increased from 17% to 24% in males and 16% to 23% in females from 1980 to 2013 (Ng et al., 2014). In addition, rates of obesity had increased from 5% to about 8% in both genders from 1980 to 2013 in developed countries (Ng et al., 2014). In the United States, rates of obesity in adolescents (aged 12 to 19 years) doubled between 1989 - 1994 (10.5%) and 2013-2014 (20.6%) (Ogden et al., 2016). In New Zealand, nearly 40% of adolescents are overweight, obese or severely obese (Mandic, Garcia Bengoechea, Coppell, & Spence, 2017a; Utter et al., 2015). In a study involving Dunedin adolescents from New Zealand conducted between 2014 and 2015, 20.5% and 6.8% of the adolescents were found to be overweight or obese, respectively (Mandic et al., 2017a).

2.2.1 Determinants of Overweight and Obesity

Determinants of overweight and obesity in children and adolescents include behavioural (Duncan et al., 2011; Mwaikambo, Leyna, Killewo, Simba, & Puoane, 2015), social and family (Duncan et al., 2011; Nesbit, Kolobe, Arnold, Sisson, & Anderson, 2014) as well as environmental factors (Nesbit et al., 2014). Behavioural factors that contribute to an increase in overweight and obesity include spending long periods of time in front of screens such as using computers (Duncan et al., 2011; Mwaikambo et al., 2015) and watching television (Nesbit et al., 2014), using MT to school (Duncan et al., 2011; Mwaikambo et al., 2015), skipping breakfast before school (Duncan et al., 2011; Mwaikambo et al., 2015) and consumption of sugary soft drinks and fried food (Mwaikambo et al., 2015). Social and family factors that are positively associated to overweight and obesity in children and adolescents include the lack of parental encouragement to be physically active, lack of parental participation in sport, having television in the bedroom and parental perception about personal safety of their child (Duncan et al., 2011; Nesbit et al., 2014). Children and adolescents of physically active parents were more likely to participate in PA compared to those with non-active parents (Duncan et al., 2011). Environmental factors that have significant impact on adolescent obesity include the presence of sidewalks and walking paths, parks, recreational centres and amenities in the neighbourhood (Nesbit et al., 2014). Therefore, a range of behavioural, social, family and environmental factors have an influence on the weight status in adolescents.

2.2.2 Health Consequences of Obesity

Obesity in children and adolescents has significant impact on their physical, emotional, and social well-being as well as academic achievements (Riazi, Shakoor, Dundas, Eiser, & McKenzie, 2010). Obese children and adolescents experienced higher rates of depression, lower self-esteem and lower health-related quality of life compared to their healthy weight counterparts (Goldfield et al., 2010; Taylor et al., 2013). Being overweight or obese was found to have negative impact on depression, self-esteem and social functioning skills in adolescents (aged 12 to 14 years) (Swallen, Reither, Haas, & Meier, 2005). In adolescents, obesity was positively associated with increased risks for hyperlipidemia, diabetes, endocrine disorders (in males only), knee disorders and hypertension (Machluf et al., 2016). In addition, adolescents who were overweight and obese were more likely to experience physical functional limitations (Swallen et al., 2005), had less positive attitude towards PA, perceived more barriers in PA engagement and were less confident that they could sustain PA participation compared to their healthy weight peers (Bourdeaudhuij et al., 2005). Taken together, those findings suggest that obesity has an adverse effect on adolescents' PA participation and in turn, has a negative impact on their physical and psychological health.

2.3 Physical Activity in Adolescents

Adolescents involved in a range of PA regularly had more opportunities to accumulate PA and establish habitual PA involvements (Kjonniksen et al., 2008) to engage in long term PA pursuits compared to those who were physically inactive. Compared to their less active counterparts, adolescents who participate in regular PA are more likely to have higher levels of cardiorespiratory fitness (Hands, Larkin, Parker, Straker, & Perry, 2009), enjoy better mental health and psychological well-being (McPhie & Rawana, 2015; Rachele, Cuddihy, Washington, & McPhail, 2014). To achieve optimal health benefits, adolescents are recommended to be engaged in ≥60 minutes of MVPA per day (Ministry of Health, 2017; Strong et al., 2005; Tremblay et al., 2016; World Health Organisation, 2011). This section discusses the benefits of regular PA in adolescents and the relationship between PA and weight status in this age group.

2.3.1 Benefits of Physical Activity in Adolescents

Physiological benefits of PA in adolescents include improved physical functions and reduced negative risk factors of health. Adolescents who participated in regular PA had higher levels of aerobic fitness (Hands et al., 2009) whilst those engaged in increased levels of high-intensity PA also had higher levels of bone density and bone mass content (Christoffersen et al., 2015). In addition, regular PA participation in adolescents promoted positive health changes in fat percentage, waist circumference, blood pressure, insulin sensitivity and cholesterol level (Vasconcellos et al., 2014). As PA helps to reduce BMI gains from adolescence to mid-adulthood (Parsons, Manor, & Power, 2006), engaging in regular PA prevents excessive weight gains in adolescents and assists them to achieve long-term weight loss and weight maintenance (Simon et al., 2014). At the same time, reducing time spent in sedentary activities and increasing vigorous intensity PA will lower cardio-metabolic risks in adolescents (Rendo-Urteaga et al., 2015) as higher levels of sedentary behaviours are associated with increased cardio-metabolic risks (Martínez-Gómez et al., 2010). In overweight or obese adolescents, a modest amount of PA could provide health benefits such as healthier cholesterol and blood lipid levels, lower adiposity and improved cardiorespiratory fitness (Janssen & Leblanc, 2010) and those with higher PA levels may improve physical fitness and reduce cardiovascular disease risk factors (Vasconcellos et al., 2014).

PA may also enhance psychological well-being and cognitive functioning in adolescents. Previous studies have found a positive correlation between frequency of PA and psychological well-being (Rees & Sabia, 2010) whereas a negative correlation was reported between PA and both anxiety and depressive symptoms in adolescents (McMahon et al., 2016). Reducing sedentary behaviours by increasing PA levels such as walking to school, had positive effect on adolescents' mental health (Asare & Danquah, 2015; Sun, Liu, & Tao, 2015) as adolescents who were physically active were less likely to experience mental problems (Biddle & Asare, 2011). In addition, adolescents who were engaged in PA experienced improvements in mental well-being as higher levels of PA were associated with lower rates of depression during mid-adolescence (McPhie & Rawana, 2015). PA was also positively associated with stress management and social affiliation in adolescents (Rachele et al., 2014). In a meta-analysis, PA interventions were found to increase positive self-concept and academic achievements in adolescents (Spruit, Assink, van Vugt, van der Put, & Stams, 2016). Improvements in self-image and psychological well-being were observed in adolescents with higher levels of physical fitness and an increased physical performance, compared to their less active counterparts (Kirkcaldy, Shephard, & Siefen, 2002). In overweight male adolescents, regular PA may help improve their physical self-esteem (Mak et al., 2016). To sum up, adolescents involved in regular PA could benefit from physiological and psychological health improvements with additional health benefits obtained by increasing their PA levels, which contributed positively to their overall well-being.

2.3.2 Physical Activity and Weight Status in Adolescents

PA may contribute to a healthier weight status and more favourable body composition in adolescents. Previous studies have found that MVPA was associated with lower levels of fat mass and BMI (Fulton et al., 2009). In addition, higher levels of MVPA were associated with lower fat mass in children at age 12 as well as in the same cohort of participants at age 14 (Riddoch et al., 2009). Moreover, vigorous intensity PA was negatively associated with BMI (Cohen et al., 2014; Jiménez-Pavón et al., 2013), waist circumference and skinfold thickness (Reicherte, Menezes, Hallal, Ekelund, & Wells, 2013) in adolescents. These findings suggest that PA levels are related to the weight status and body composition in adolescents.

PA levels accumulated outside school hours and during leisure time may influence adolescents' weight status. Male adolescents with higher levels of PA participation outside school hours had lower rates of overweight and obesity (Mota, Ribeiro, Carvalho, & Santos, 2010). In addition, female adolescents who consistently engaged in high levels of PA during leisure time from pre-puberty to early adulthood had higher lean mass gain compared to those who had consistently low or decreasing leisure time PA (Völgyi et al., 2011). On the other hand, declining levels of PA in adolescents were significantly associated with increasing BMI and adiposity (Kimm et al., 2005) and those who were physically inactive were more likely to be overweight compared to their physically-active peers (Stevens et al., 2007). In female adolescents, a decline in moderate intensity PA over time resulted in an increase in BMI, percent body fat, skinfolds and waist circumference (Kettaneh et al., 2005). Findings from a comparison study in Great Britain and Saudi Arabia reported that adolescents with higher BMI had lower levels of PA and greater amount of time spent in sedentary activities compared to those with lower BMI in both countries (Al-Nakeeb et al., 2012). Taken together the existing evidence suggests that regular PA may promote healthy weight management in adolescents and high levels of PA could be effective in preventing overweight and obesity in this age group. In addition, PA accumulated outside school time as well as during leisure time could potentially increase adolescents' daily PA.

However, with significant declines of PA among children and adolescents over the last few decades (Salmon & Timperio, 2007) and increase in sedentary behaviours in adolescents (Ruiz et al., 2011; Smith, Berdel, Nowak, Heinrich, & Schulz, 2016) result in an increasing proportion of adolescents engaging in insufficient levels of daily PA to meet PA recommendations (Ruiz et al., 2011; Smith et al., 2016; Ting, Mukherjee, & Hwa, 2015). Furthermore, the effects of declining PA in the younger population was aggravated by age-related transition from childhood to adolescence (Dumith et al., 2011; Olds et al., 2011; Troiano et al., 2008; Trost et al., 2002) as well as progression from primary to secondary school (Larouche et al., 2013). Hence, in order for adolescents to meet the recommended PA guidelines (Strong et al., 2005; Tremblay et al., 2016; World Health Organisation, 2011), regular and consistent source of PA, including potential PA opportunities outside school hours such as using AT to and from school, should be encouraged.

2.4 Transport to School Habits in Adolescents

Transport to school habits in children and adolescents in both developed and developing countries have changed over the last three decades. In the United States, walking and cycling to school in children and adolescents have declined significantly from 40.7% in 1969 to 12.9% in 2001 mainly due to an increase in distance from home to school (McDonald, 2007). Similar trends of increased MT and decreased AT have been observed in many countries including Canada (Gray et al., 2014), Australia (van der Ploeg et al., 2008), New Zealand (Ministry of Transport, 2015), Czech Republic (Dygryn et al., 2015), Germany (Reimers et al., 2013), Finland (Yang et al., 2014) and Vietnam (Trang, Hong, & Dibley, 2012). In New Zealand, adolescents' transport to school habits have changed over the past 25 years with a decline in rates of cycling to school in secondary school students from 19% in 1989-1990 to 3% in 2010-2014 (Ministry of Transport, 2015). During the same period, walking to school in adolescents had remained relatively stable at 26% in 1989-1990 to between 26%-29% in 2010-2014 (Ministry of Transport, 2015). However, from 2008-2012, a greater number of New Zealand adolescents who walked to school switched to the use of public transport as their daily transport mode to school (Ministry of Transport, 2015).

2.4.1 Factors Influencing Adolescents' Transport to School

Multiple factors influence the modes of transport to school in adolescents and have significant impact on promoting or hindering the use of AT (Babey, Hastert, Huang, & Brown, 2009; Gropp, Pickett, & Janssen, 2012; Mandic et al., 2015a; Robertson-Wilson, Leatherdale, & Wong, 2008; Simons et al., 2013; Van Dyck, De Bourdeaudhuij, Cardon, & Deforche, 2010; Verhoeven et al., 2016). These factors include personal, social and environmental variables which are closely related to adolescents as an individual as well as their social and physical environments (Babey et al., 2009; Gropp et al., 2012; Mandic et al., 2015a; Robertson-Wilson et al., 2008; Simons et al., 2013; Van Dyck et al., 2010; Verhoeven et al., 2016).

Various personal factors influence the choice of transport modes to school in adolescents including gender (Babey et al., 2009; Robertson-Wilson et al., 2008; Stock et al., 2012; Van Dyck et al., 2010; Wong, Faulkner, Buliung, & Irving, 2011), age (Mandic et al., 2015a; Robertson-Wilson et al., 2008), family income (Babey et al., 2009; Stock et al., 2012), family vehicle ownership (Mandic et al., 2015a), PA behaviours of adolescents (Robertson-Wilson et al., 2008; Wong et al., 2011), level of autonomy (Simons et al., 2013; Verhoeven et al., 2016; Wong et al., 2011) as well as financial and health concerns (Simons et al., 2013). Previous studies have found that girls were less likely to use AT to school compared to boys (Babey et al., 2009; Robertson-Wilson et al., 2008; Stock et al., 2012; Van Dyck et al., 2010; Wong et al., 2011). Older adolescents were less likely to use AT to school compared to younger adolescents (Mandic et al., 2015a; Robertson-Wilson et al., 2008). Adolescents from low-income families were more likely to use AT to school compared to those from higher income families (Babey et al., 2009; Stock et al., 2012). In addition, adolescents living in households with fewer vehicles were more likely to use AT to school compared to those from households with higher vehicle ownership (Mandic et al., 2015a). Compared to their less active peers, adolescents who were regularly engaged in more PA were more likely to use AT to school (Robertson-Wilson et al., 2008; Wong et al., 2011). Higher level of autonomy provided by using AT to school, such as cycling, offered greater independent mobility for adolescents without being reliant on others for their transportation needs, and thus, resulted in higher rates of AT to school (Simons et al., 2013). In addition, being involved in their own decision-making on their school transport mode also increased the likelihood of adolescents using AT to school (Wong et al., 2011). Financial concerns such as greater expenses incurred in using MT (driver's license, buying a car, expenses for public transport) compared to AT encouraged more adolescents to use AT to school (Simons et al., 2013). Finally, perceived health benefits derived from walking or cycling daily to school promoted higher usage of AT to school in adolescents compared to MT (Simons et al., 2013). Therefore, personal factors including gender, age, family income, vehicle ownership, PA behaviours, level of autonomy as well as financial and health concerns relating to the use of school transport influence adolescents' choices in using various modes of transport to school.

Social factors that are associated with adolescents' choices of school transport modes include influences from family and peers (Babey et al., 2009; Simons et al., 2013; Van Dyck et al., 2010; Verhoeven et al., 2016), opportunities to socialise with peers during the journey to school (Mandic et al., 2015a; Simons et al., 2013) and social norms relating to the use of school transport modes (Verhoeven et al., 2016). Previous studies have found that PA levels of family members and peers were positively associated with adolescents' choices of using AT to school (Babey et al., 2009; Van Dyck et al., 2010). In addition, transport choices of peers may influence adolescents' decisions to use the same mode of transport to school as well (Simons et al., 2013). Adolescents' perceptions of socialising opportunities on their journey to school was positively associated with walking or cycling to school (Mandic et al., 2015a; Simons et al., 2013). Social norms such as acceptable behaviours of using AT to school determine the likelihood of adolescents using AT to school (Verhoeven et al., 2016). Therefore, social factors such as family and peer influences, perceived socialising opportunities during school journeys as well as existing social norms are important considerations for adolescents in determining their transport mode to school.

Environmental factors that influence adolescents' choice of school transport modes include perceived neighbourhood safety (Gropp et al., 2012; Mandic et al., 2015a; Simons et al., 2013), neighbourhood walkability (Gropp et al., 2012; Van Dyck et al., 2010; Verhoeven et al., 2016), availability of infrastructure for AT (Gropp et al., 2012; Simons et al., 2013), school location and proximity of home to school (Babey et al., 2009; Mandic et al., 2015a; Robertson-Wilson et al., 2008; Van Dyck et al., 2010), time required to travel to school (Simons et al., 2013) and the weather (Simons et al., 2013).

Perceived neighbourhood safety such as a good standard of traffic safety (Gropp et al., 2012; Mandic et al., 2015a; Simons et al., 2013) and perceived high neighbourhood walkability encouraged adolescents to use AT to school (Van Dyck et al., 2010). In addition, availability of cycling paths with roads that were not too busy (Simons et al., 2013) and high percentage of streets with sidewalks (Dalton et al., 2011; Gropp et al., 2012) were positively associated with AT to school in adolescents. Adolescents living at close proximity (within 2 km) to school were more likely to use AT to school compared to those who lived further from school (Babey et al., 2009; Dalton et al., 2011; Mandic et al., 2015a; Van Dyck et al., 2010). In contrast, adolescents attending rural schools were less likely to use AT and more likely to rely on MT as they usually lived further away from their schools (Babey et al., 2009; Robertson-Wilson et al., 2008). Using AT such as cycling was seen by older adolescents as a good way to travel short distances as it was fast and allowed for shorter travel time (Simons et al., 2013). When the weather was good, adolescents were more likely to choose AT over MT to commute to school (Simons et al., 2013). Therefore, various environmental factors such as adolescents' perceived safety and walkability of their neighbourhood, availability of infrastructure that makes it easier to walk or cycle to school, the location of school (urban vs rural), proximity to school, time required to travel to school as well as the weather affect adolescents' transport to school decisions.

In summary, personal, social and environmental variables are important factors that influence perceptions of adolescents and ultimately, have an impact on their decisions in choosing a particular mode of transport to school.

2.4.2 Benefits of Active Transport in the General Population

In adults, substantial health benefits as such reduction of cardiovascular diseases, diabetes, colon and breast cancers and depression were reported in countries with higher prevalence of AT compared to countries with lower rates of AT (Gotschi et al., 2015). In addition, cycling as a form of AT, was associated with improved mental and physical well-being as well as reduced sickness and absence in the working population (Mytton, Panter, & Ogilvie, 2016). At a macro level, policies developed for the general population to promote AT such as walking and cycling achieved positive impacts on health, including greater reduction of carbon dioxide (Rojas-Rueda et al., 2016; Woodcock, Givoni, & Morgan, 2013) and noise (Rojas-Rueda et al., 2016), reduced emissions as well as improvement in air quality (Rojas-Rueda et al., 2016; Woodcock et al., 2013), reduced traffic congestion (Rojas-Rueda et al., 2016) and reduced rates of road traffic injuries (Woodcock et al., 2013).

2.4.3 Benefits of Active Transport to School in Adolescents

In adolescents, AT to school is associated with health benefits such as higher levels of physical fitness (Andersen et al., 2011; Chillón et al., 2010; Larouche et al., 2014), lower BMI and prevention of adverse weight gains (Arango et al., 2011; Drake et al., 2012; Jauregui, Medina, Salvo, Barquera, & Rivera-Dommarco, 2015; Larouche et al., 2014; Mendoza et al., 2011; Ostergaard et al., 2012; Tudor-Locke et al., 2003). Particularly, cycling to school is associated to higher levels of cardiovascular fitness in adolescents compared to MT to school (Cooper et al., 2006b). Adolescents who cycled to school were found to have higher aerobic power and cardiovascular fitness (Andersen, Lawlor, Cooper, Froberg, & Anderssen, 2009; Chillón et al., 2010), higher muscle endurance and flexibility (Andersen et al., 2009), lower BMI and waist circumference (Larouche et al., 2014; Ostergaard et al., 2012), lower cholesterol levels (Andersen et al., 2011; Larouche et al., 2014), better glucose metabolism (Andersen et al., 2011) and a lower composite cardiovascular disease risk factor score (Andersen et al., 2011) compared to those who did not cycle at all. In addition, female adolescents who used AT to school had improved cognitive process skills such as response inhibition and selective attention. However, these associations were not observed in male adolescents (Van Dijk, De Groot, Van Acker, Savelberg, & Kirschner, 2014). Therefore, AT to school is associated with positive health benefits in adolescents which contributes to improving their overall quality of life.

2.5 Active Transport to School, Physical Activity and Fitness in Adolescents

AT to school provides an opportunity for adolescents to increase daily levels of PA. In general, adolescents who use AT to school are physically fitter and more active compared to MT users (Andersen et al., 2009; Chillón et al., 2010; Cooper et al., 2008; Larouche et al., 2014) and are more likely to meet the daily PA recommendations (Abbott et al., 2009; Chillón et al., 2010; Roth, Millett, & Mindell, 2012).

2.5.1 Weekly and Daily Physical Activity in Adolescents

Most previous studies that involved objectively-measured PA using accelerometers in adolescents reported higher overall daily MVPA (Alexander et al., 2005; Chillón et al., 2011; Chillón et al., 2010; Larouche et al., 2014; Saksvig et al., 2007) in AT users compared to MT users to school, with the exception of one study (Nilsson et al., 2009a). Higher levels of PA were reported in Estonian and Swedish male adolescents who used AT to school compared to those who used MT (Chillón et al., 2010). In a study of adolescents from ten European cities, AT was positively associated with greater amounts of MVPA and overall PA and this association was stronger in males compared to females (Chillón et al., 2011). In addition, adolescents who spent more time in AT across the week had higher levels of daily PA compared to those who spent less time in AT (Chillón et al., 2011). American female adolescents who walked to and from school had significantly higher levels of total PA and MVPA for the entire day compared to non-walkers (Saksvig et al., 2007). Among Canadian adolescents, those who used AT to school accumulated greater amounts of daily MVPA compared to MT users (Larouche et al., 2014). English adolescents who walked to school accumulated higher overall MVPA throughout the day compared to those who used MT (Alexander et al., 2005). However, in one study, no association between AT to school and MVPA was found in European adolescents from Norway, Estonia and Portugal (Nilsson et al., 2009a). The authors in that study attributed the differences in MVPA cut-points measured using accelerometers in previous studies could have resulted in the differences between findings from those previous studies and their study (Nilsson et al., 2009a). Therefore, most but not all previous studies have found positive association between AT to school and PA levels in adolescents.

2.5.2 School Day and Weekend Physical Activity in Adolescents

Adolescents who used AT to school accumulated greater amounts of school day MVPA measured by accelerometers (Alexander et al., 2005) and accumulated steps measured by pedometers (Abbott et al., 2009; Duncan et al., 2008; Hohepa et al., 2008) compared to those who used MT to school. In addition, AT to school contributed to higher school day MVPA compared to weekend MVPA in adolescents (Carver et al., 2011). English adolescents who walked both to and from school accumulated greatest amount of MVPA on school days compared to those who walked one way to school and those who used MT to school (Alexander et al., 2005). Another previous study that examined the association of AT and MVPA across childhood and adolescence in two cohorts, aged 5 to 6 years and 10 to 12 years, reported that AT was associated with greater amounts of MVPA on school days than weekend days in adolescents (Carver et al., 2011). Two previous studies involving New Zealand female adolescents with pedometer-measured steps reported that AT users accumulated more school day steps compared to MT users to school (Duncan et al., 2008; Hohepa et al., 2008). In addition, female adolescents who used AT to school achieved more steps on a school day than a weekend day (Duncan et al., 2008; Hohepa et al., 2008). Similarly, walking to or from school was associated to significantly greater number of school day steps in Australian adolescents compared to non-walkers (Abbott et al., 2009). Therefore, previous studies have found associations between AT to school and greater amounts of objectively-measured MVPA and daily step counts on school days compared to MT in adolescents.

2.5.3 Active Transport and Fitness Level in Adolescents

Several previous studies have found that cycling to school is associated to higher levels of physical fitness in adolescents (Andersen et al., 2009; Chillón et al., 2010; Larouche et al., 2014). Danish adolescents who cycled to school had higher aerobic power, muscle endurance and flexibility compared to those who walked to school (Andersen et al., 2009). In another study, children (aged 9 to 10 years) and adolescents (aged 15 to 16 years) from Estonia and Sweden who cycled to school attained higher levels of cardiorespiratory fitness than those who used MT to school (Chillón et al., 2010). In addition, Canadian adolescents who cycled at least 1 hour per week had greater aerobic fitness compared to those who did not cycle to school (Larouche et al., 2014). Thus, previous findings from the above studies have shown an association between AT to school and fitness levels in adolescents who used cycling as an active mode of transport to school. Therefore, cycling to school, but not necessarily walking to school, may be a way to improve fitness in adolescents.

2.5.4 Before and after School Physical Activity in Adolescents

Although adolescents who used AT to school achieved higher levels of overall PA compared to those who used MT, most previous studies did not assess adolescents' PA levels during their school commute times, specifically, before and after school hours. Only three previous studies examined AT to school in adolescents during before and after school hours (Mendoza et al., 2011; Saksvig et al., 2007; Saksvig et al., 2012). In American adolescents who used AT to school, a positive association was found between AT to school and MVPA accumulated before and after school hours (Mendoza et al., 2011). However in that study, MVPA that was accumulated during school commute times could likely include school-related PA or after school sports, and thus, could not be attributable to only using AT to school (Mendoza et al., 2011). In another study, American female adolescents who walked to school during before and after school hours accumulated higher levels of MVPA on an average school day compared to those who did not walk to school (Saksvig et al., 2007). Similar results were reported in the subsequent study involving the same cohort of adolescents two years later, which also found that adolescents who walked to school accumulated greater minutes of MVPA during before and after school hours compared to non-walkers (Saksvig et al., 2012). Therefore, higher levels of PA were accumulated by adolescents who used AT to school during their school commute before and after school.

To sum up, adolescents who used AT to school had higher levels of overall PA including higher energy expenditure, increase in step counts or greater amount of MVPA and better fitness compared to MT. In addition, adolescents who used AT to school accumulated higher levels of PA during school commute times as well as on school days compared to weekend days.

2.6 Active Transport to School and Weight Status in Adolescents

AT to school is a good source of daily PA which contributes to higher levels of PA in adolescents. Increased PA has a positive impact on weight status and adiposity in children and adolescents. However, results in the findings from previous studies vary and there is inconsistent evidence of the association between AT to school and healthy weight status in adolescents.

Several previous studies suggested that compared to MT, AT to school is associated with healthier weight status in adolescents. In American adolescents, AT to school was inversely related to obesity (Drake et al., 2012). Colombian adolescents who used AT to school had lower likelihood of becoming overweight compared to those who used MT (Arango et al., 2011). In Danish adolescents, cycling to school was associated with lower likelihood of being overweight compared to MT as well as walking to school (Ostergaard et al., 2012). In Mexican adolescents, more time spent in AT was associated with lower rates of overweight and obesity (Jauregui et al., 2015). These studies demonstrate a positive association between active modes of transport to school and healthy weight status in adolescents.

In addition, some previous studies have reported that AT to school may be associated with lower BMI and more favourable body composition in adolescents. American adolescents who were engaged in higher levels of AT to school had lower BMI scores and skinfold measures (Mendoza et al., 2011). Similarly, Chinese adolescents who were AT users to school had lower BMI, percentage of body fat and waist circumference compared MT users (Sun et al., 2015). Danish adolescents who cycled to school had lower BMI compared to MT users (Ostergaard et al., 2012). In addition, Danish children who did not cycle to school at baseline (9 years of age) and had changed their transport mode to cycling 6 years later at follow-up (15 years of age) had lower waist circumference compared to those who used MT (Andersen et al., 2011). In a longitudinal prospective study that involved a large cohort of Brazilian adolescents, using AT to school at 15 and 18 years of age was associated with lower levels of central body fat in males only (Martínez-Gómez et al., 2014). Hence, the above studies demonstrate positive correlations between AT to school and lower BMI and percentage of body fat in adolescents.

The amount of time spent on AT and the distance between home and school may also have an impact on PA levels and weight status in adolescents. An increased time spent on AT to school provides a greater amount of accumulated PA during AT to school and therefore could reduce risks of overweight and obesity in adolescents (Jauregui et al., 2015). In one study, AT to school was associated with a decrease in fat mass levels as the distance between adolescents' home and school increased (Landsberg et al., 2008). Thus, factors such as time spent on AT to school and the distance travelled from home to school may have significant impact on the effects of AT on weight status in adolescents.

Contrary to these findings, several previous studies found little or no significant association between AT to school and weight status in adolescents. AT to school was not significantly associated with fat mass or BMI in German adolescents although the authors reported a significant association between distance of AT to school and fat mass of adolescents in that study (Landsberg et al., 2008). Hence, there is a need to consider distance to school and the amount of time adolescents spent in AT to school when examining the associations between AT and weight- or body composition-related variables in adolescents (Landsberg et al., 2008). In another study involving English adolescents, walking to school was not significantly associated with healthier weight status (Baig et al., 2009). However, findings in that study may not be generalizable to adolescents from higher socio-economic status families as the majority of adolescents in that study were from deprived communities of lower social-economic status (Baig et al., 2009). Similarly, findings from a study involving Portuguese adolescents reported no association between AT to school and BMI (Mota et al., 2006). Findings from those studies demonstrate no significant association between AT to school and healthier weight status in adolescents. Therefore, inconsistent findings are observed regarding the relationship between AT to school and weight status in this age group.

2.6.1 Relationship between Active Transport to School, Physical Activity and Weight Status in Adolescents

The relationship between AT to school and weight status in adolescents is likely mediated by the impact of AT to school on overall PA in adolescents. Only a few previous studies examined the complex relationship between AT to school, PA and weight status in adolescents. In Canadian adolescents, although utilitarian walking and cycling to school were associated with higher daily MVPA (Larouche et al., 2014), adolescents who cycled at least 1 hour per week to school had lower BMI and waist circumference compared to non-cyclists (Larouche et al., 2014). Another study in Filipino adolescents compared PA and self-reported transport modes to school by walking, MT or combined walking and MT (Tudor-Locke et al., 2003). Compared to MT, AT to school (walking) was associated with increased energy expenditure in adolescents of both genders (Tudor-Locke et al., 2003). In addition, the increased energy expenditure was also associated with the prevention of weight gain as male and female adolescents who used AT to school expended 8840 kcal/year and 6640 kcal/year, respectively (Tudor-Locke et al., 2003). On the other hand, adolescents who used MT to school reported a yearly positive energy balance that would result in a weight gain of 0.9 to 1.4 kilograms per year (Tudor-Locke et al., 2003). Another study that examined AT to school and its influence on PA and weight status found that American adolescents who used AT to school achieved higher levels of overall daily MVPA and lower levels of body fatness and adiposity (Mendoza et al., 2011). That study had also assessed AT during school commute times and found that higher levels of MVPA accumulated before and after school were associated with lower waist circumference in adolescents (Mendoza et al., 2011). Therefore, the use of

AT to and from school provided more opportunities for adolescents to increase their PA levels and to achieve a healthier weight status compared to those who used MT to school.

To sum up, although several studies reported that AT to school is associated to healthy weight status and body composition in adolescents, this association is not consistent across all studies. Hence, there is inconclusive evidence that using AT school could contribute to achieving healthy weight status in adolescents.

2.7 Overall Summary

The review of existing literature suggests that there are positive associations between AT to school and overall PA levels in adolescents as well as PA accumulated on school days and during school commute times (an hour before and after school). However, previous studies mainly reported overall daily PA in adolescents with a paucity of studies that examined adolescents' PA during school commute times. Only three previous studies examined PA during the school commute times (to and from school) (Mendoza et al., 2011; Saksvig et al., 2007; Saksvig et al., 2012). In addition, studies that were conducted on New Zealand adolescents measured PA using pedometers rather than accelerometers. Furthermore, most previous studies did not take into account the use of a combined mode of transport (AT+MT) to school. To date, only one previous study had examined the use of a combined mode of transport (AT+MT) to school in adolescents (Tudor-Locke et al., 2003). The main limitation of previous studies that examined the association between AT to school and PA levels in adolescents was the use of a cross-sectional study design and therefore the causal relationship between AT and PA cannot be established. As the use of pedometers in studies conducted on New Zealand adolescents did not measure PA intensities, future studies in New Zealand adolescents should use objectively-measured PA to determine the amount of MVPA. Hence, further research is necessary to examine objectively-measured PA levels to obtain valid PA data throughout the week, on school days and weekend days and also during school commute times. There is also a need to further examine the various modes of transport to school that would allow a more comprehensive representation of how adolescents travel to school, which include a combined AT+MT, in addition to AT only and MT only. Therefore, the primary aim of this Master's research project was to compare objectively-measured PA levels in adolescents using different modes of school transport (AT only, MT only and AT+MT). PA levels were assessed during the week, on school days and weekend days as well as during school commute times. This primary aim of the study addressed current knowledge gaps related to objectively-measured PA in New Zealand adolescents, use of a combined AT+MT transport mode to school and the assessment of PA during school commute times.

The evidence presented on the relationship between AT to school and weight status in adolescents is inconclusive, suggesting the need for further research to examine this complex relationship. Only three previous studies examined the relationship of AT to school, PA and weight status in adolescents (Larouche et al., 2014; Mendoza et al., 2011; Tudor-Locke et al., 2003). These studies found positive association in relation to the use of AT to school with higher levels of PA and more favourable weight status observed in adolescents who used AT versus MT to school. However, no previous study examined such relationship among New Zealand adolescents. Moreover, only one study examined the association of AT to school, PA during commute to and from school and weight status in adolescents (Mendoza et al., 2011). Limitations of the previous studies that examined the relationship of AT to school, PA and weight status include the cross-sectional study design, self-reported BMI in some of these studies (Drake et al., 2012; Ostergaard et al., 2012) and self-reported PA levels in other studies (Arango et al., 2011; Baig et al., 2009; Drake et al., 2012; Jauregui et al., 2015; Landsberg et al., 2008; Martínez-Gómez et al., 2014; Mota et al., 2006; Ostergaard et al., 2012; Sun et al., 2015). The use of a cross-sectional study design precludes conclusions about the causal relationships between AT, PA and weight status in adolescents. Both self-reported BMI and PA levels by adolescents may not provide accurate measurements of adolescents' weight status and accumulated PA levels, respectively, due to presence of reporting bias (Sun et al., 2015) which could result in underestimation or overestimation of outcome measures in those studies (Drake et al., 2012; Sallis & Saelens, 2000). To ensure valid data in examining the relationship between adolescents' transport to school behaviours, PA and weight status, future studies should use objectively measured PA, height and weight to determine adolescents' PA levels and weight status, respectively. Future studies should also examine the association between AT and weight status in adolescents from other geographical settings to enable comparison of findings across different countries. Increased levels of PA throughout the day would assist adolescents in achieving and maintaining healthier weight status. Therefore, the secondary aim of this study was designed to address the current knowledge gaps by examining the relationship of objectively-measured PA and weight status in adolescents who used different modes of transport to school (AT only, MT only and AT+MT).

CHAPTER 3

3 Methodology

3.1 Study Purpose

The purpose of this study was to compare PA and weight status in New Zealand adolescents using different modes of transport to school. For this study, adolescents' modes of transport to school were categorised into three transport groups: AT only, MT only and AT+MT. The primary aim of this study was to examine the association between adolescents' transport modes to school and PA levels throughout the week, on school days and weekend days as well as during different times of the school day (an hour before school (8 am - 9 am), an hour after school (3 pm - 4 pm) and late after school hours (4 pm - 8 pm)). The secondary aim was to examine the relationship between PA and weight status in adolescents across three transport groups. For the secondary aim, weight status was categorised into two groups: "underweight or healthy weight" and "overweight or obese".

3.2 Study Design and Setting

Data reported in this thesis are part of the larger Built Environment and Active Transport to School (BEATS) Study (Mandic et al., 2016). The BEATS Study is a cross-sectional study that examined AT to school in Dunedin adolescents accounting for individual, social, environmental and policy influences. The BEATS Study was conducted in Dunedin, New Zealand (2013 - 2017). The overall BEATS Study consisted of six different sub-projects which involved the use of both qualitative and quantitative methods to collect data from students, parents, teachers and principals: BEATS Student Survey, BEATS Student Focus Groups, BEATS Parental Survey, BEATS Parental Focus Groups, BEATS Teacher Survey, BEATS Teachers' Focus Groups and School Principal Interview (Mandic et al., 2016). Data analysed for this thesis were collected as a part of the BEATS Student Survey conducted in 2014 and 2015 (Mandic et al., 2016). The BEATS Student Survey included an online survey, anthropometry measurements, mapping of the route to school and, in a sub-group of participants, PA assessment using accelerometers (Mandic et al., 2016). All twelve Dunedin secondary schools participated in this study (Figure 1). The outcome measures used in this thesis were transport to school habits, total weekly PA, average school day PA, average weekend day PA, PA at different times of the school day (before school, early after school and late after school hours) and weight status in adolescents. The BEATS Study was approved by the University of Otago Ethics Committee (reference number 13/203; 19 July 2013) (Appendix A).

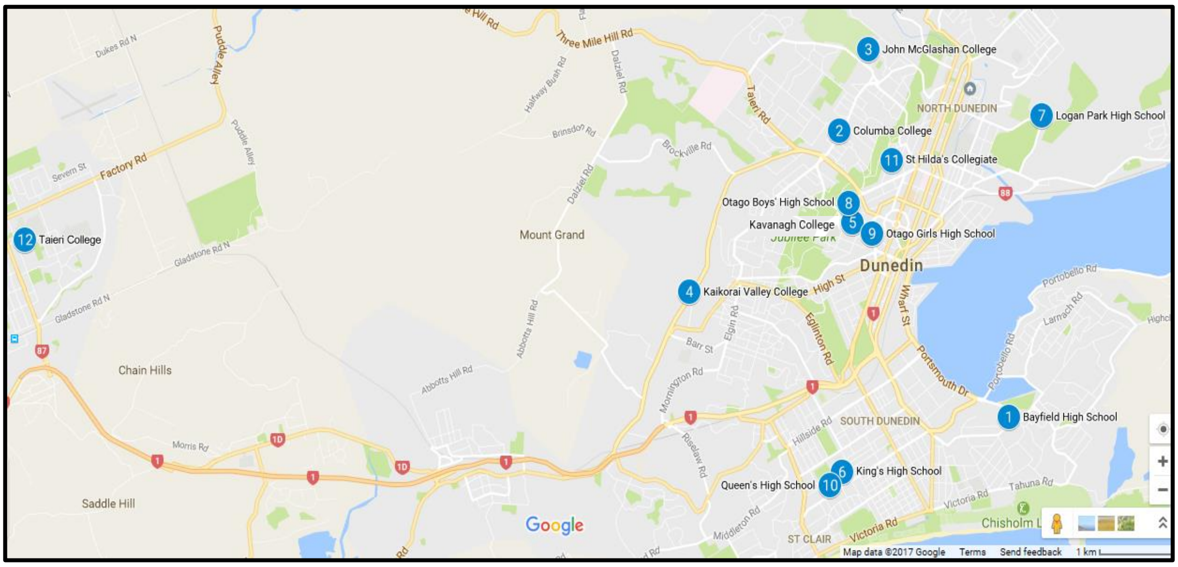

Figure 1. Locations of all twelve secondary schools in Dunedin, New Zealand which participated in the BEATS Study.

Map data: Google Maps, 2017

3.3 Participants

A total of 1780 adolescents in school years 9 to 13 from all twelve Dunedin secondary schools participated in the BEATS Student Survey between February 2014 and June 2015 (Mandic et al., 2015b; Mandic et al., 2016).

3.3.1 Recruitment of Schools

The BEATS Study investigators provided details about the study and invited all twelve Dunedin secondary schools to participate in this study at the meeting of the Dunedin Secondary School Principals Association in August 2013. Subsequently, the BEATS Study investigators met with school principals of all interested secondary schools to discuss the details of the study and school involvement. By 2014, all twelve Dunedin secondary schools agreed to take part in the BEATS Study. The BEATS Study Principal Investigator and the Study coordinator conducted meetings to discuss the details of the study with the school principals and other relevant staff members at each school.

3.3.2 Recruitment of Participants

Recruitment of adolescents was done through the schools and the BEATS Study was advertised in the schools' newsletters. Each school selected 2 to 4 classes per school year from years 9 to 13 to be invited to participate in the BEATS Student Survey. A study information package was given to all invited adolescents at the respective schools 1 to 3 weeks before the scheduled data collection dates. Due to the limited available funding for this study, a sample size calculation was not carried out for adolescents who participated in the PA assessment in this study.

In this thesis, only study information pertaining to BEATS Student Survey is appended, including information for both invited adolescents and their parents. Depending on the school's preference, either parental opt-in (active) or parental opt-out (passive) consent was used for adolescents aged 13 to 15 years at the time of the survey. The appendix of this thesis includes the relevant information sheets and consent forms used in schools that chose parental opt-out consent for adolescents 13 to 15 years of age. The study information package for parents included parental/guardian information sheet (Appendix B) and parental/guardian consent form (Appendix C). Study information package for adolescents included student information pamphlet (Appendix D), student PA assessment pamphlet (Appendix E), as well as student consent forms for student survey (Appendix F) and PA assessment (Appendix G). In addition, school principals also sent out emails with the study information to all invited adolescents and their parents. Study packages in prepaid envelopes were given to each school for parents who did not have an email address or internet access.

In order to participate in this study, all adolescents signed paper consent for taking part in the BEATS Student Survey as well as an additional consent for the PA assessment. For adolescents under 16 years of age, their parents signed either the parental opt-in or opt-out consent, depending on school's preference, to indicate agreement to their child's participation in the study. Parents had the option to sign their consent either online or on paper. Adolescents were informed of the rewards that they could receive as participants in this study. For each school, all adolescents who completed the BEATS Student Survey were entered into a draw for a chance to win one of up to 5 movie vouchers per school. In addition, adolescents who participated in the PA assessment received a graph on their PA for one day and a $5 book voucher upon returning the device, with an additional $5 book voucher if they had valid accelerometer data (7 consecutive days for at least 12 hours per day).

3.3.2.1 Inclusion and Exclusion Criteria

The inclusion criteria for the BEATS Student Survey were adolescents of age 13 to 18 years, both genders, attending a secondary school in Dunedin, a signed student consent form and, if applicable, a signed parental consent form for adolescents under 16 years of age in schools that required parental opt-in (active) consent (Mandic et al., 2016). Exclusion criteria were age under 13 years, lack of a signed student consent form and/or no signed parental consent form if it was required by participant's school (Mandic et al., 2016).

3.3.3 Participants Recruited for the Current Study

For the research presented in this thesis, participants were adolescents who completed the BEATS Student Survey and had a valid signed consent for the PA assessment using accelerometers.

A total of 314 adolescents were included in the current analysis (Figure 2). Adolescents with incomplete student or parental consents (n=79), invalid surveys (n=38), missing survey data (n=48), no consent for PA assessment (n=1041), boarding at schools (n=162), and incomplete or invalid accelerometer data (n=98) were excluded from the research reported in this thesis. To be included in the analysis for this thesis, adolescents also had to have valid accelerometer data for at least 3 week days and 1 weekend day based on previously determined validity criteria for PA assessment using accelerometers (Corder, Ekelund, Steele, Wareham, & Brage, 2008; Riddoch et al., 2004; Trost, Pate, Freedson, Sallis, & Taylor, 2000).

3.4 Measurement Procedures

This study used quantitative data collection methods including an online survey, anthropometric measurements and objectively-measured PA using accelerometers. On the day of the scheduled data collection, study identification numbers (study IDs) were issued to adolescents for their online surveys and anthropometry forms to ensure anonymised data collection. Adolescents completed an online survey and anthropometry measurements during class time and were given accelerometers approximately 1 to 3 weeks after completion of the survey.

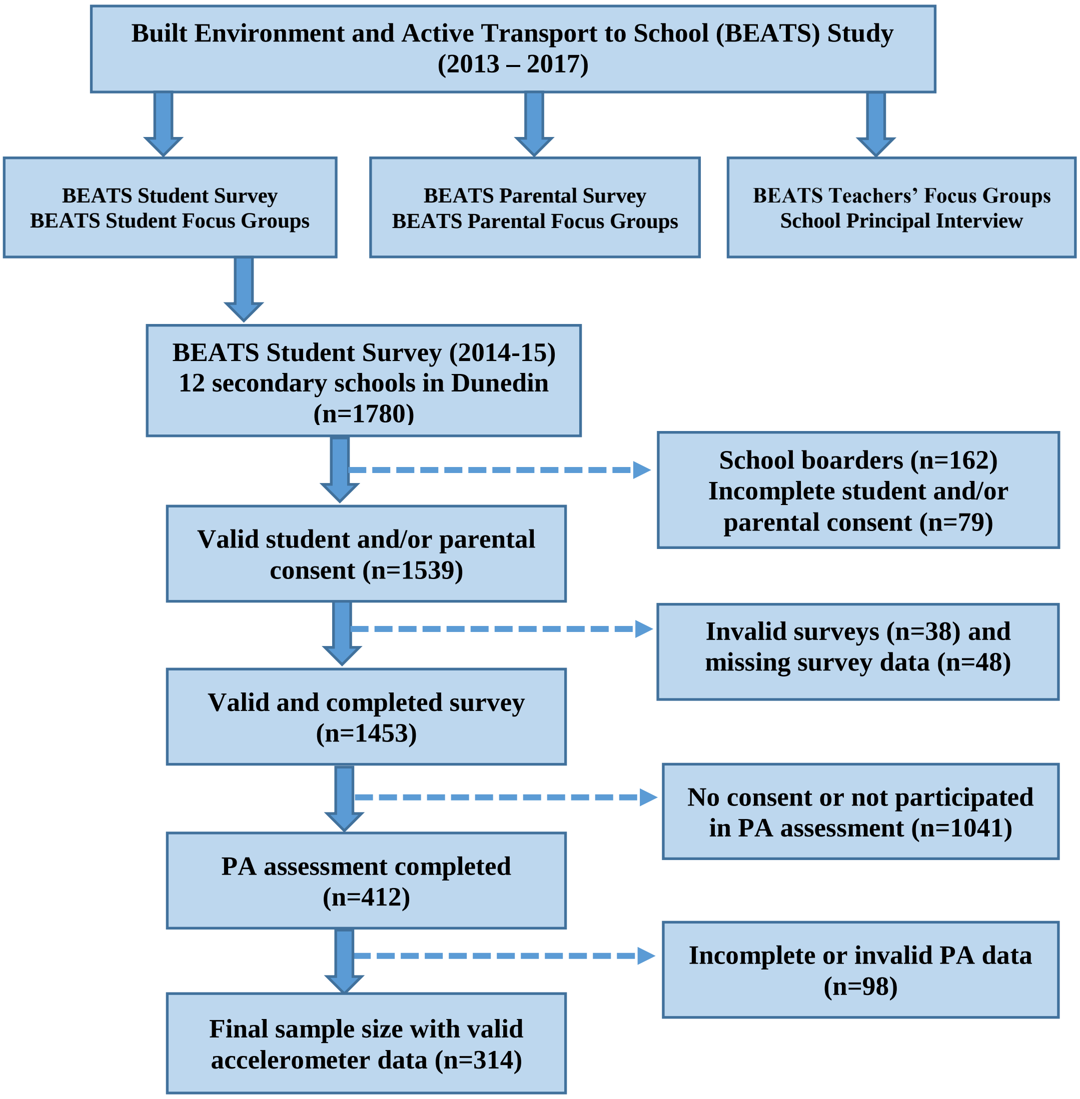

Figure 2. Flow chart of final sample size in the current study

3.4.1 Online Survey

Adolescents completed a 30- to 40-minute online questionnaire using Qualtrics survey software (Mandic et al., 2016). At the start of the online survey, research assistants informed adolescents about the purpose of the BEATS Student Survey and the details of the data collection process. The survey was delivered and completed online in the presence of 3 to 5 research assistants and a teacher during one school period at the school's computer laboratory. The presence of research assistants allowed for close monitoring of adolescents who were completing the survey which ensured response validity. The overall BEATS Student Survey included questions on demographics, reasons for choosing a particular school, transport to school habits, motivations and barriers to walking and cycling to school, perceived neighbourhood environment, health behaviours, perceptions of driving and use of information communication technology (Mandic et al., 2016). All survey questions in the BEATS Student Survey have been developed for secondary school students and most of the questions have been validated and used in similar populations (Mandic et al., 2016). For the purpose of this thesis, responses to questions on sociodemographic characteristics and transport to school habits of adolescents were used in the data analysis.

3.4.1.1 Sociodemographic Characteristics

Sociodemographic characteristics collected as a part of the BEATS Student Survey included date of birth, gender, ethnicity, name of school, school year, home address, number of bikes available for use to get to school (none, one, two or more) and number of vehicles at home (none, one, two or more) (Mandic et al., 2017b). Age of adolescents was calculated from the date of birth at the time of the survey. Home address data were collected from adolescents to match address codes with data from the New Zealand Index of Deprivation Study, which was then used to determine adolescents' socio-economic status (Salmond, Crampton, King, & Waldegrave, 2006). The deprivation index was recoded from the original 10-point scale to five categories: low (1-2), middle-low (3-4), middle (5-6), middle-high (7-8) and highest (9-10). Distance from home to school was determined using the Geographic Information Systems analysis based on adolescents' home addresses (Mandic et al., 2016).

3.4.1.2 Transport to School Habits

Adolescents' transport to school habits were assessed using the question "How do you usually travel to school?" for different modes of transport ("by car - driven by others", "by car - driving myself", "by school bus", "by public transport", "on foot", "by bike", and "other") (Mandic et al., 2017b). Adolescents were asked to rate the frequency of usage for each mode of transport with response categories "never", "rarely", "sometimes", "most of the time" and "all of the time" (Mandic et al., 2017b). To be considered as a usual mode of transport to school, adolescents would use the particular mode of transport "most of the time" or "all of the time" as described elsewhere (Mandic et al., 2017b).

Adolescents were also asked if they used more than one mode of transport to school using a question "Do you usually use more than one mode of transport on a single journey to school (for example, bus and walking)?" Adolescents who responded "Yes" to this question were asked to specify their respective modes of transport and provided more information on their usage of multi-mode transport to school. Adolescents who used more than one mode of transport to school "most of the time" or "all of the time" were coded as using multi-mode transport to school (Mandic et al., 2017b).

Based on the collated data, adolescents' dominant modes of transport to school were determined and used as a basis for classification into three transport groups (AT only, MT only or AT+MT). Adolescents who used walking, cycling on a bicycle or riding a non-motorised scooter to school "most/all of the time" were classified as AT only group. Adolescents who used car, school bus or public transport to school "most/all of the time" were classified as MT only group. Adolescents who used a combination of active (walking or cycling) and motorised transport (car, school bus or public transport) to school "most/all of the time" were classified as AT+MT group as described previously (Mandic et al., 2017b).

3.4.2 Anthropometry Assessment

At the time of the online survey, adolescents had their height, weight and waist circumference measured to determine their weight status. Adolescents' anthropometric measurements were taken by research assistants at a screened-off area of the classroom to ensure privacy and confidentiality.

Adolescents had their height and weight measured in their school uniforms and were asked only to remove their jackets and shoes (Mandic et al., 2017a). Height was measured by a custom-made portable stadiometer, recorded in centimetres to the nearest one decimal place (Mandic et al., 2016). Weight was measured by an electronic scale (A&D scale UC321, A&D Medical), recorded in kilograms to the nearest 2 decimal places (Mandic et al., 2016). BMI (kg/m^2) was calculated as weight (kg) divided by height (m) squared. BMI standards were used to classify obesity using international age- and gender-specific cut-points for adolescents (Cole et al., 2000). Adolescents were categorised into one of the four weight status categories: "underweight", "healthy weight", "overweight" and "obese". Waist circumference was measured twice, in standing position, just above adolescents' belly button at the end of a normal exhalation with a metal measuring tape (MURATEC-KDS CORP) (Mandic et al., 2016). Waist circumference was measured in centimetres, to the nearest one decimal place and an average of two readings was recorded (Mandic et al., 2016). Adolescents were allowed to choose if they preferred to have their waist circumference taken over their top layer of clothes or directly over their skin. The anthropometric measurements for each adolescent was recorded into an anthropometry form and initialled by the research assistant who took the measurements. Anthropometry data were collected discretely. If participants wished, they could see their measurements but the measurements/numbers were not verbalised.

3.4.3 Physical Activity Assessment

In this study, adolescents' PA was measured objectively using accelerometers. PA can be measured using a wide range of methods including subjective, criterion and objective measures (Vanhees et al., 2005). Subjective measures include self-reported PA using questionnaires, interviews, activity logs and PA diaries (Vanhees et al., 2005). Criterion measures include the use of doubly labelled water, indirect calorimetry and direct observation to assess PA (Vanhees et al., 2005). Objective measures of PA include the use of activity monitors such as accelerometers and pedometers (De Vries et al., 2009; Kohl, Fulton, & Caspersen, 2000; Trost, 2001, 2007; Vanhees et al., 2005). To accurately measure PA in children and adolescents, PA needs to be measured objectively using valid and reliable methods such as accelerometers (Trost, 2007).

3.4.3.1 Objective Measurement of Physical Activity using Accelerometers

Accelerometers provide objective measures of PA in population-based studies (Audrey, Bell, Hughes, & Campbell, 2012) by quantifying the amount and intensity of PA (Reilly et al., 2008; Trost, 2007). Accelerometers are small, lightweight and portable devices that are easy to use and provide minimal intrusion in participants' movement during daily activities (Trost, 2007; Zhang, Werner, Sun, Pi-Sunyer, & Boozer, 2003). More importantly, accelerometers are equipped with data storage capabilities (De Vries et al., 2009; Freedson & Miller, 2000; Vanhees et al., 2005) that monitor movements in more than one plane and are able to measure the magnitude and direction of acceleration (Vanhees et al., 2005). The use of accelerometers is a practical and accurate method to measure free-living PA in children and adolescents (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008; Trost, 2007) and is a valid method to measure PA in adolescents (De Vries et al., 2009).

Previous studies have reported both strengths and limitations of using accelerometers in assessing daily PA (Ainsworth, 2009; Trost, 2001; Vanhees et al., 2005; Zhang et al., 2003). The strengths include the objective measurement of real time intensity and duration of daily PA (Freedson & Miller, 2000; Trost, 2001, 2007; Zhang et al., 2003) and the ability to accurately detect sedentary behaviours as well as light, moderate and vigorous intensities of PA (Ainsworth, 2009; Trost, 2007; Vanhees et al., 2005). Although accelerometers are able to monitor all movements, these devices provide limited measurements of upper body movements when worn on the hip (Trost, McIver, & Pate, 2005; Vanhees et al., 2005), movement in graded terrain (Trost, 2007; Vanhees et al., 2005) and in activities such as cycling (Trost, 2007; Trost et al., 2002; Vanhees et al., 2005) or swimming (Vanhees et al., 2005).

Seven days of PA monitoring using accelerometers provided reliable estimates of PA in children and adolescents which reflected differences in week day and weekend activities as well as daily activity patterns (Trost, 2001, 2007; Trost et al., 2005; Trost et al., 2000). Accelerometers are recommended to be worn in a comfortable, unobtrusive location of the body and should be firmly attached to the body (Matthews, Hagströmer, Pober, & Bowles, 2012)**.** Accelerometers worn on the hip and lower back provide valid PA measurements (Trost et al., 2005). Placement of accelerometers on the right hip is part of the standard protocol in The International Physical Activity and Environment Network (IPEN) study (refer to http://www.ipenproject.org). In addition, various countries involved in the IPEN Adolescents study had adopted the internationally developed set of standardised protocol for PA measurement by getting adolescents to wear accelerometers on their waists above the right hip to detect PA (De Meester et al., 2012; Hinckson et al., 2017; Logan, Harris, Duncan, Hinckson, & Schofield, 2016; Molina-García, Queralt, Adams, Conway, & Sallis, 2017).

Participants' adherence to wearing an accelerometer throughout the day is crucial to prevent incomplete accelerometer data (Trost et al., 2005). Strategies can be devised to ensure that participants attain valid wear time compliance when using accelerometers (Trost et al., 2005) such as getting participants to complete a daily monitoring log (Trost et al., 2005), sending personal activity graphs (Audrey et al., 2012), implementing rewards for complying with the required wear time and timely return of device (Audrey et al., 2012; Trost et al., 2005), providing participants the opportunities of regular contact with the research team (Audrey et al., 2012) by making reminder calls or sending text messages to participants (Trost et al., 2005) as well as giving advance notice of the study and the protocols of wearing the device to sports officials, coaches or teachers who are directly related to the participants (Trost et al., 2005). In addition, other factors that may affect wear time validity in adolescents include the comfort of wearing an accelerometer, the use and type of incentives as reward for participation in PA assessment, changes in adolescents' curriculum time in school as well as the need to participate in activities (such as cycling, rollerblading, contact sports and water sports) that are not suited with the use of accelerometers (Audrey et al., 2012).

When PA is measured using accelerometers, recorded body movements are converted to quantifiable units of signals referred as activity counts, which are grouped over a selected time interval known as epoch (Baquet, Stratton, Van Praagh, & Berthoin, 2007). In analysing PA data, the use of accelerometer cut-points to categorise activity into sedentary activities as well as light, moderate and vigorous intensity PA is influenced by the choice of epoch length, which may affect the classification of PA intensities that accurately represent PA in the specific age groups (Trost et al., 2005). Compared to epochs of 60 seconds, recording accelerometer data in epochs of 10 and 30 seconds are more likely to detect short bursts of MVPA which are typical characteristics of PA behaviours in children and adolescents (Trost et al., 2005). On the other hand, epochs of 60 seconds may lead to an underestimation of MVPA in children and adolescents (Reilly et al., 2008; Trost et al., 2005) as the longer epoch interval could result in the loss of accounting for more frequent short periods of vigorous PA in children and adolescents (Evenson et al., 2008). As there is no single standardised cut-point criterion used to classify different intensities of PA, large variations in cut-point values were used in different studies (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013b; Reilly et al., 2008; Trost, 2007). In addition, various cut-points were derived from calibration studies (Evenson et al., 2008; Freedson, Pober, & Janz, 2005; Mattocks et al., 2007; Puyau, Adolph, Vohra, & Butte, 2002; Romanzini, Petroski, Ohara, Dourado, & Reichert, 2014). Among the various cut-points developed in calibration studies, Evenson cut-points provided better classification accuracy for MVPA among children of all ages and was recommended for use to estimate time spent in different PA intensities in children and adolescents (Trost, Loprinzi, Moore, & Pfeiffer, 2011).

Amongst the various models of accelerometers, ActiGraph was most commonly used in studies involving PA and substantial research has been done with the use of ActiGraph accelerometers (Ainsworth, 2009; De Vries et al., 2009; Trost, 2007). Previous validity studies have reported ActiGraph as a valid device to measure PA in children and adolescents (Evenson et al., 2008; Freedson et al., 2005; Ott, Pate, Trost, Ward, & Saunders, 2000; Puyau et al., 2002; Romanzini et al., 2014). In a previous calibration study that compared cut-point values for different accelerometer models (ActiGraph GT3X, Actical and RT3) to accurately classify PA intensity levels in adolescents, cut-points developed for sedentary activities and MVPA using the vertical axis of the ActiGraph accelerometer were similar to the validated Evenson cut-points. Thus, the cut-points developed for sedentary activities and MVPA with the use of the ActiGraph accelerometer were valid for monitoring PA levels in adolescents (Romanzini et al., 2014).

In summary, accelerometers are devices that are used to objectively measure PA in adolescents. Although there are variations in the cut-points used in different models of accelerometers, most of the cut-points used in previous studies have been validated in calibration studies (Evenson et al., 2008; Freedson et al., 2005; Mattocks et al., 2007; Ott et al., 2000; Puyau et al., 2002; Romanzini et al., 2014) and have proven to be reasonably accurate to classify PA of different intensities in adolescents.

3.4.3.2 Procedures for Physical Activity Measurement in the Current Study

Adolescents who consented to participate in the PA assessment (n=412) received their accelerometer (ActiGraph, GT3XPlus, Pensacola, FL, USA) at their school (Mandic et al., 2016). Before issuing accelerometers to adolescents, research assistants initialised the devices by entering adolescents' date of birth, gender, height and weight measurements into ActiGraph software (ActiLife 6 Data Analysis Software). In the next step, an accelerometer device code was tagged to each respective participant to keep track of the device. Accelerometers were programmed to measure adolescents' PA for 8 consecutive days, starting on the day after adolescents received their devices and to account for the potential need to wear the device for an additional day if any one of the days was missed during the scheduled 7-day period as recommended in a previous study (Trost et al., 2000).

Adolescents were briefed on how to use an accelerometer and the proper way to wear the device through a demonstration by research assistants. Adolescents also received verbal and written instructions about returning their device back to school after PA assessment. Adolescents were instructed to wear their accelerometers at least 12 hours daily for 7 consecutive days and take it off only during sleep and water-based activities. Adolescents wore their accelerometers underneath or on top of their clothing around their waist, just above their right hipbone to ensure validity of results (Trost et al., 2005). Each adolescent was given an activity meter log to record details of wear time, school start and end times as well as the times if they had to remove their accelerometer and the reason(s) for removing it for more than 30 minutes. Getting adolescents to complete their daily activity meter log helps promote greater accelerometer wear compliance (Trost et al., 2005). In addition, adolescents received emails and/or text reminders from research assistants to wear their accelerometer during the 7-day assessment period to comply with the requested wear time (Audrey et al., 2012; Trost et al., 2005).

After the 7-day tracking of their PA, adolescents returned their accelerometers and activity meter logs to their schools. Research assistants collected accelerometers and logs from each school. Adolescents received rewards for participating in the PA assessment as described above and as per recommendations (Audrey et al., 2012; Trost et al., 2005). Briefly, adolescents received a graph which reflected their PA for one day and a $5 book voucher for returning their accelerometer. An additional $5 book voucher was given to adolescents if they wore their accelerometer for 7 consecutive days with at least 12 hours each day.

PA data from accelerometers were downloaded using ActiGraph software in 10-second epochs and measured in average counts per minute (cpm) (Trost et al., 2005). A minimum of 10 hours per day for at least 5 days was set as the valid wear time criteria for accelerometers (Sherar et al., 2011; Trost, 2007). Research assistants ascertained the wear time validity of PA data to ensure that adolescents had worn their accelerometers for a minimum of 5 consecutive days with at least 10 hours per day, which included at least 3 school days and 1 weekend day of PA in order to account for school day and weekend differences (Corder et al., 2008; Riddoch et al., 2004). These wear time criteria also ensured that multiple data points were available for calculating PA assessment throughout school day (before, immediately after and late after school).

For the purpose of the quality assurance, the processing of all accelerometer data for the BEATS Study was done by the specialised data analysis service of the MeterPlus company in San Diego, USA. In this study, PA data were analysed using MeterPlus Software (MeterPlus, San Diego, CA, USA) with Evenson cut-points (sedentary: 0 - 25 cpm; light intensity PA: 26 - 573 cpm; moderate intensity PA: 574 - 1002 cpm; vigorous intensity PA: ≥1003 cpm) (Evenson et al., 2008). In addition, a recommended low frequency extension filter was used, which was sensitive to movement, especially for light and moderate intensity PA (Cain, Conway, Adams, Husak, & Sallis, 2013a). The data used in the thesis of this research student were obtained from MeterPlus specialised data analysis service to ensure the highest quality of data from the BEATS Study to be used for this analysis and subsequent publications.

PA variables obtained from the accelerometer data included light intensity PA, moderate intensity PA, vigorous intensity PA, MVPA, time spent in sedentary activities as well as wear and non-wear times. All variables were reported as daily averages as well as averages for school days and weekend days. MVPA was calculated as a sum of moderate intensity PA and vigorous intensity PA data for a particular time interval. PA data used in this study included total minutes of MVPA accumulated throughout the day, without the specific minimum length of activity bouts. Twenty-minute sedentary bout length was used to classify non-activity time periods (Cain et al., 2013b; Esliger, Copeland, Barnes, & Tremblay, 2005). In addition, PA and time spent in sedentary activities during particular times of a school day which included one hour before school (8 am - 9 am) and after school (3 pm - 4 pm) as well as late after school period (4 pm - 8 pm) were also obtained. For each of those time periods during the school day, a minimum of 75% of wear time was required for inclusion in data analysis (i.e., ≥45 minutes of wear time for an hour before and after school and ≥3 hours of wear time for late after school). Out of 412 adolescents who opted in and completed PA assessment in this study, 314 (76.2%) had valid accelerometer data in the current study.

3.5 Data Analysis

Demographic characteristics were analysed using descriptive statistics. For the primary aim of the study, continuous variables were compared across the three transport groups (AT only, MT only, AT+MT) using one-way ANOVA with Tukey post-hoc multiple comparisons. Categorical variables were compared across the three transport groups using Chi Square test. For the secondary aim of the study, Chi Square test was used to analyse categorical variables between the two weight status groups ("underweight or healthy weight" and "overweight or obese"). Independent t-test was used for comparing continuous variables between the two weight status groups. Continuous variables were reported as means ±SD and categorical variables were reported as frequencies (%) with p-values of <0.05 indicating statistically significant differences between the groups. IBM SPSS Statistical software version 22.0 was used for data analysis.

CHAPTER 4

4 Results

4.1 Transport to School and Physical Activity in Adolescents

For the primary purpose of this study, PA levels throughout the week, on school days and weekend days as well as during different times of the school day were compared across the three transport groups (AT only, MT only and AT+MT).

4.1.1 Sociodemographic Characteristics

A total of 314 adolescents from twelve secondary schools in Dunedin who completed the BEATS Student Survey, anthropometry measurements and had valid accelerometer data were included in this analysis. The total study sample consisted of mostly female adolescents of New Zealand European ethnicity (Table 1). Overall, 23.2% of the adolescents used AT only, 58.9% of them used MT only and 17.9% of them used AT+MT to school (Table 2). More than half of all adolescents had at least 2 bicycles at home that were available for them to cycle to school (Table 1). More than three quarters of all adolescents lived in households that owned at least 2 vehicles (Table 1).

On the average, AT only group lived closer to school compared to MT only and AT+MT groups (Table 2). MT only group travelled the longest distance to school amongst the three transport groups (Table 2). AT only group had the highest proportion of New Zealand Europeans and lowest proportion of Māori adolescents compared to MT only and AT+MT groups (Table 2). AT only group had the lowest proportion of adolescents living in households that owned at least 2 vehicles compared to the two other transport groups (Table 2). There were no significant differences in age, gender, neighbourhood deprivation score and bicycle ownership among the three transport groups (Table 2).

Table 1. Sociodemographic characteristics of the total sample

	Total sample (n= 314)
Age (years)	14.7 ± 1.4
Gender [n(%)]	
Males	103 (32.8%)
Females	211 (67.2%)
Ethnicity [n(%)]	
New Zealand European	242 (77.1%)
Māori	22 (7.0%)
Other	50 (15.9%)
Neighbourhood deprivation score [n(%)]	
1 (least deprived)	97 (31.5%)
2	74 (24.0%)
3	53 (17.2%)
4	51 (16.6%)
5 (most deprived)	33 (10.7%)
Distance to school (m)	6213 ± 6925
Number of bikes available to use to get to school [n(%)]	
None	66 (21.0%)
One	71 (22.6%)
Two or more	177 (56.4%)
Number of vehicles at home [n(%)]	
None	8 (2.5%)
One	85 (27.1%)
Two or more	221 (70.4%)

Table 2. Sociodemographic characteristics across three transport groups

	Active transport only (AT only) (n= 73)	Active and motorized transport (AT+MT) (n=56)	Motorized transport only (MT only) (n= 185)	p-value
Age (years)	14.7 ± 1.2	14.5 ± 1.3	14.8 ± 1.5	0.583
Gender [n(%)]				
Males	28 (38.4%)	19 (33.9%)	56 (30.3%)	
Females	45 (61.6%)	37 (66.1%)	129 (69.7%)	0.451
Ethnicity [n(%)]				
New Zealand European	59 (80.8%)	40 (71.4%)	143 (77.3%)	
Māori	2 (2.7%)	9 (16.1%)	11 (5.9%)	
Other	12 (16.4%)	7 (12.5%)	31 (16.8%)	0.047
Neighbourhood deprivation score [n(%)]				
1 (least deprived)	15 (20.5%)	17 (30.9%)	65 (36.1%)	
2	17 (23.3%)	16 (29.1%)	41 (22.8%)	
3	13 (17.8%)	9 (16.4%)	31 (17.2%)	
4	18 (24.7%)	9 (16.4%)	24 (13.3%)	
5 (most deprived)	10 (13.7%)	4 (7.3%)	19 (10.6%)	0.265
Distance to school (m)	1509 ± 1245[a,b]	7577 ± 7228	7696 ± 7349	<0.001
Number of bikes available to use to get to school [n(%)]				
None	15 (20.5%)	13 (23.2%)	38 (20.5%)	
One	17 (23.3%)	10 (17.9%)	44 (23.8%)	
Two or more	41 (56.2%)	33 (58.9%)	103 (55.7%)	0.921
Number of vehicles at home [n(%)]				
None	4 (5.5%)	1 (1.8%)	3 (1.6%)	
One	36 (49.3%)	15 (26.8%)	34 (18.4%)	
Two or more	33 (45.2%)	40 (71.4%)	148 (80.0%)	<0.001

[a] p<0.05 AT only versus AT+MT; [b] p<0.05 AT only versus MT only; [c] p<0.05 AT+MT versus MT only

4.1.2 Meeting Physical Activity Guidelines

Overall, less than half of adolescents accumulated ≥60 minutes of MVPA per day with greater proportion of adolescents engaged in ≥60 minutes of MVPA per day on school days compared to weekend days (Figure 3).

Throughout the week and on school days, approximately half of the adolescents who used AT only and AT+MT to school met PA guidelines compared to approximately one third of those who used MT only (Table 3, Table 4, Figure 4). Throughout the week, significantly higher proportion of adolescents in AT only group accumulated ≥60 minutes of MVPA per day compared to MT only group (Figure 4). On school days, significantly higher proportions of adolescents in AT only and AT+MT groups accumulated ≥60 minutes of MVPA per day compared to MT only group (Figure 4). On weekend days, between one quarter to one third of the adolescents accumulated ≥60 minutes of MVPA per day with no significant differences across the three transport groups (Figure 4).

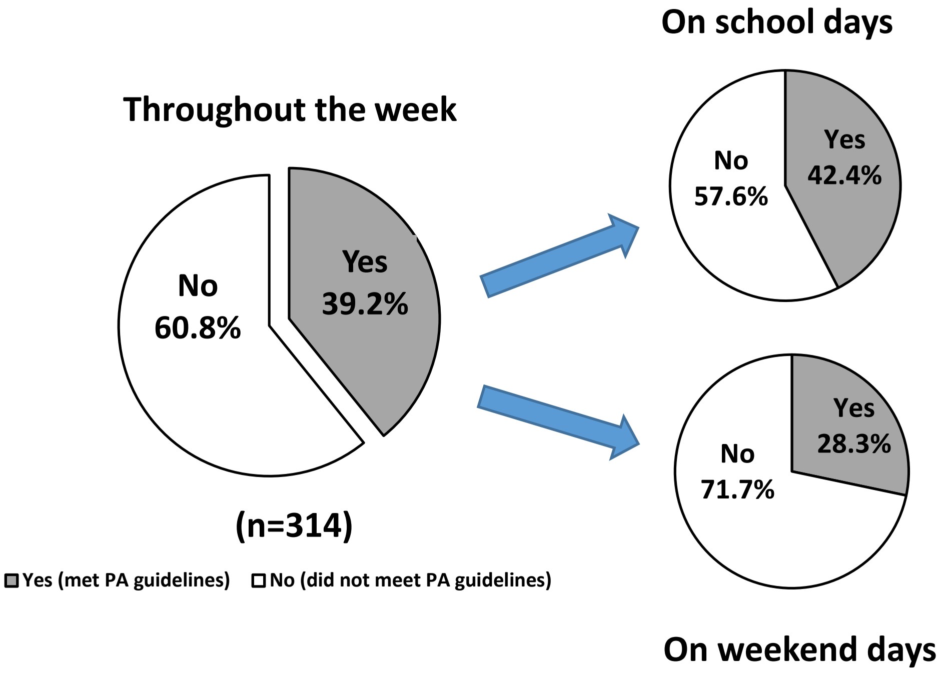

Figure 3. Proportion of adolescents in the total sample who met physical activity guidelines throughout the week, on school days and weekend days

Table 3. Physical activity throughout the week across three transport groups

	Total sample (n=314)	Active transport only (AT only) (n=73)	Active and motorized transport (AT+MT) (n=56)	Motorized transport only (MT only) (n=185)	p-value
Average daily activity throughout the week (min)					
Sedentary activities	575.9 ± 81.1	583.6 ± 75.6	564.3 ± 72.1	576.4 ± 85.6	0.402
Light PA	193.2 ± 47.5	179.3 ± 49.3[a,b]	203.3 ± 44.4	195.6 ± 46.8	0.009
Moderate PA	33.4 ± 11.5	34.6 ± 13.9	36.7 ± 10.6[c]	32.0 ± 10.6	0.016
Vigorous PA	22.4 ± 13.9	26.6 ± 16.3[b]	22.9 ± 15.6	20.5 ± 11.8	0.006
MVPA	55.8 ± 21.1	61.2 ± 23.2[b]	59.6 ± 21.7	52.5 ± 19.6	0.004
Wear and non-wear times (min)					
Wear time	824.9 ± 63.8	824.2 ± 61.6	827.1 ± 60.7	824.6 ± 65.8	0.960
Non-wear time	610.8 ± 63.9	611.9 ± 61.9	608.5 ± 60.8	611.1 ± 65.9	0.952
Percent of wear time (%)					
Sedentary activities	69.7 ± 7.0	70.8 ± 7.1	68.2 ± 6.3	69.8 ± 7.2	0.111
Light PA	23.5 ± 5.8	21.8 ± 5.7[a,b]	24.7 ± 5.4	23.8 ± 5.8	0.008
Moderate PA	4.1 ± 1.4	4.2 ± 1.7	4.4 ± 1.2[c]	3.9 ± 1.3	0.019
Vigorous PA	2.7 ± 1.7	3.3 ± 2.0[b]	2.8 ± 1.8	2.5 ± 1.4	0.005
MVPA	6.8 ± 2.5	7.5 ± 2.8[b]	7.2 ± 2.5	6.4 ± 2.4	0.003
Meeting PA guidelines [n(%)]					
(≥60 min of MVPA/day)	123 (39.2%)	35 (47.9%)[b]	26 (46.4%)	62 (33.5%)	0.048

[a] $p<0.05$ AT only versus AT+MT; [b] $p<0.05$ AT only versus MT only; [c] $p<0.05$ AT+MT versus MT only

PA: physical activity; MVPA: moderate-to-vigorous physical activity

Table 4. Physical activity during school days across three transport groups

	Total sample (n=314)	Active transport only (AT only) (n=73)	Active and motorized transport (AT+MT) (n=56)	Motorized transport only (MT only) (n=185)	p-value
Average daily activity during school days (min)					
Sedentary activities	591.7 ± 86.4	596.9 ± 75.0	582.1 ± 84.7	592.5 ± 91.1	0.619
Light PA	192.9 ± 49.0	179.8 ± 49.1[a]	204.0 ± 47.4	194.7 ± 48.6	0.015
Moderate PA	34.9 ± 11.7	36.6 ± 14.0[b]	39.5 ± 11.8[c]	32.8 ± 10.1	<0.001
Vigorous PA	23.6 ± 14.5	28.7 ± 16.7[b]	23.7 ± 15.8	21.6 ± 12.6	0.002
MVPA	58.5 ± 21.0	65.3 ± 22.4[b]	63.2 ± 21.9[c]	54.4 ± 19.1	<0.001
Wear and non-wear times (min)					
Wear time	843.1 ± 73.5	842.0 ± 66.2	849.3 ± 77.0	841.6 ± 75.4	0.783
Non-wear time	592.6 ± 73.6	594.0 ± 66.5	586.2 ± 77.1	593.9 ± 75.5	0.776
Meeting PA guidelines [n(%)] (≥60 MVPA/day)	133 (42.4%)	42 (57.5%)[b]	29 (51.8%)[c]	62 (33.5%)	0.001

[a] p<0.05 AT only versus AT+MT; [b] p<0.05 AT only versus MT only; [c] p<0.05 AT+MT versus MT only

PA: physical activity; MVPA: moderate-to-vigorous physical activity

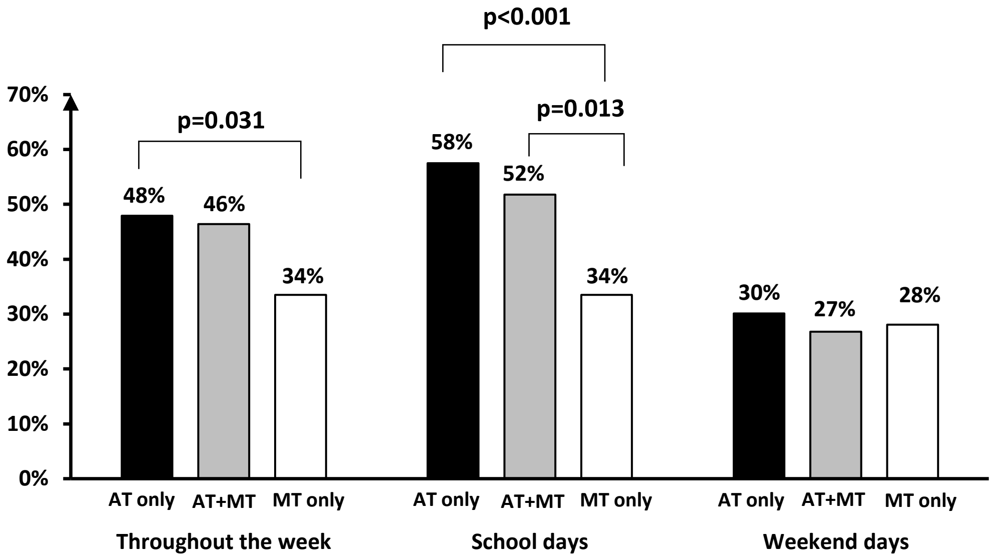

Figure 4. Proportion of adolescents who met physical activity guidelines throughout the week, on school days and weekend days across three transport groups

AT only: active transport only; AT+MT: active and motorised transport; MT only: motorised transport only

4.1.3 Weekly and Daily Physical Activity

Overall, adolescents wore accelerometers for an average of 14 hours per day. Throughout the week, adolescents spent more than two thirds of the accelerometer wear time in sedentary activities (approximately 10 hours per day) and less than one tenth in MVPA (<1 hour per day) (Table 3). On school days and weekend days, adolescents spent between 8 to 10 hours of their time in sedentary activities and approximately 3 hours in light intensity PA (Table 4 and Table 5). Adolescents spent approximately 10 minutes more in MVPA on school days (58.5 minutes) compared to weekend days (48.1 minutes) (Table 4, Table 5).

Across the three transport groups, significant differences were observed in light, moderate, vigorous intensity PA and MVPA throughout the week (Table 3). Compared to MT only group, AT only group spent significantly more time in vigorous intensity PA and MVPA and accumulated on average 8.7 minutes of MVPA more than MT only group (Table 3). AT only group spent the least amount of time in light intensity PA compared to both MT only and AT+MT groups (Table 3). AT+MT group spent significantly more time in moderate intensity PA compared to MT only group (Table 3). No significant differences across the three transport groups were found in the amount of time spent in sedentary activities on a daily basis (range: 9.4 hours to 9.7 hours per day on average) (Table 3).

Table 5. Physical activity during weekend days across three transport groups

	Total sample (n=314)	Active transport only (AT only) (n=73)	Active and motorized transport (AT+MT) (n=56)	Motorized transport only (MT only) (n=185)	p-value
Average daily activity during weekend days (min)					
Sedentary activities	531.5 ± 103.3	543.2 ± 101.9	513.6 ± 95.4	532.2 ± 105.9	0.271
Light PA	193.8 ± 64.1	177.5 ± 64.9[b]	198.0 ± 66.0	198.9 ± 62.5	0.046
Moderate PA	29.2 ± 19.7	29.4 ± 21.5	28.3 ± 16.6	29.4 ± 20.0	0.934
Vigorous PA	18.9 ± 19.0	21.6 ± 21.5	20.6 ± 22.8	17.4 ± 16.5	0.220
MVPA	48.1 ± 34.6	50.9 ± 36.2	48.9 ± 35.9	46.8 ± 33.7	0.679
Wear and non-wear times (min)					
Wear time	773.4 ± 81.0	771.6 ± 71.9	760.5 ± 76.1	778.0 ± 85.6	0.363
Non-wear time	662.5 ± 81.2	664.6 ± 72.1	675.3 ± 76.5	657.8 ± 85.8	0.362
Meeting PA guidelines [n(%)] (≥60 MVPA/day)	89 (28.3%)	22 (30.1%)	15 (26.8%)	52 (28.1%)	0.910

[a] $p<0.05$ AT only versus AT+MT; [b] $p<0.05$ AT only versus MT only; [c] $p<0.05$ AT+MT versus MT only

PA: physical activity; MVPA: moderate-to-vigorous physical activity

4.1.4 School Day Physical Activity across Three Transport Groups

On school days, AT only group spent significantly more time in moderate and vigorous intensity PA and MVPA but less time in light intensity PA compared to MT only group (Table 4). On school days, AT only and AT+MT groups spent significantly more time in MVPA compared to MT only group (AT only: 65.3 minutes; AT+MT: 63.2 minutes; MT only: 54.4 minutes) (Table 4). On the average, AT only and AT+MT groups accumulated 10.9 minutes and 8.8 minutes more MVPA per day in a school day, respectively, than MT only group (Table 4). The amount of time spent in sedentary activities on school days was not significantly different across the three transport groups and it ranged from 9.7 hours to 10 hours per day on average (Table 4).

4.1.5 Weekend Physical Activity across Three Transport Groups

On weekend days, average daily PA (light, moderate, vigorous intensity PA and MVPA) and time spent in sedentary activities did not differ significantly across the three transport groups, with the exception of significantly more light intensity PA accumulated by MT only group compared to AT only group (Table 5). Across the three transport groups, adolescents on average spent between 8.6 hours to 9.1 hours per day in sedentary activities and <1 hour per day in MVPA on weekend days (Table 5).

4.1.6 Before and after School Physical Activity on School Days

Overall, in an hour before school (8 am - 9 am) and an hour immediately after school (3 pm - 4 pm), adolescents spent about half their time (approximately 53% to 56%) in sedentary activities, one third of their time (approximately 30%) in light intensity PA and 13% to 17% (approximately 8 to 10 minutes) in MVPA (Table 6, Table 7). During the 4-hour period late after school (4 pm - 8 pm), adolescents spent nearly three quarters of their time (approximately 70%) in sedentary activities, about one quarter of their time (approximately 24%) in light intensity PA and approximately 6% (15 minutes) in MVPA (Table 8).

In an hour before school (8 am - 9 am), AT only and AT+MT groups spent significantly more time in moderate and vigorous intensity PA and MVPA compared to MT only group (Table 6). In addition, AT only group spent significantly more time in vigorous intensity PA and MVPA compared to both MT only and AT+MT groups (Table 6). During this time, AT only group accumulated twice as much time in MVPA compared to MT only group (AT: 12.7 minutes vs MT: 5.6 minutes) and AT+MT group accumulated 4.2 minutes more in MVPA compared to MT only group (AT+MT: 9.8 minutes vs MT: 5.6 minutes) (Table 6). The MT only group spent significantly more time in light intensity PA and sedentary activities compared to AT only group (Table 6).

In an hour immediately after school (3 pm - 4 pm), AT only group spent significantly more time in moderate and vigorous intensity PA and MVPA and significantly less time in sedentary activities compared to MT only group (Table 7). Compared to AT+MT group, AT only group spent significantly more time in vigorous intensity PA and MVPA and significantly less time in light intensity PA during that 1-hour period (Table 7). During this period, AT only and AT+MT groups accumulated additional 4.9 minutes and

1.5 minutes in MVPA, respectively, compared to MT only group (AT: 13.3 minutes; AT+MT: 9.9 minutes; MT: 8.4 minutes) (Table 7).

During late after school hours (4 pm - 8 pm), PA (light, moderate and vigorous intensity PA and MVPA) and time spent in sedentary activities were not significantly different among the three transport groups (Table 8). Adolescents spent approximately 70% of their time in sedentary activities and 6% to 7% in MVPA (approximately 14 to 17 minutes) during this 4-hour period (Table 8).

Table 6. Physical activity in an hour before school (8 am - 9 am) across three transport groups

	Total sample (n= 314)	Active transport only (AT only) (n= 73)	Active and motorized transport (AT+MT) (n= 56)	Motorized transport only (MT only) (n= 185)	p-value
Average activity in an hour before school (8 am - 9 am) (min)					
Sedentary activities	32.3 ± 8.1	28.7 ± 9.6[b]	31.8 ± 8.3	33.9 ± 6.8	<0.001
Light PA	17.6 ± 6.0	15.7 ± 6.7[b]	17.3 ± 5.7	18.5 ± 5.7	0.004
Moderate PA	4.5 ± 3.8	6.8 ± 5.2[b]	5.7 ± 4.3[c]	3.3 ± 2.0	<0.001
Vigorous PA	3.4 ± 4.3	5.9 ± 5.6[a,b]	4.1 ± 4.9[c]	2.3 ± 2.9	<0.001
MVPA	8.0 ± 6.4	12.7 ± 7.5[a,b]	9.8 ± 6.7[c]	5.6 ± 4.3	<0.001
Wear and non-wear times (min)					
Wear time	57.9 ± 2.7	57.0 ± 3.4[a,b]	58.9 ± 1.9	58.0 ± 2.5	<0.001
Non-wear time	1.7 ± 2.7	2.8 ± 3.4[a,b]	0.7 ± 2.0	1.7 ± 2.5	<0.001
Percent of wear time (%)					
Sedentary activities	55.8 ± 13.9	50.3 ± 17.0[b]	54.0 ± 14.1	58.5 ± 11.6	<0.001
Light PA	30.4 ± 10.4	27.5 ± 11.7[b]	29.3 ± 9.6	31.9 ± 9.8	0.008
Moderate PA	7.8 ± 6.5	11.9 ± 9.2[b]	9.7 ± 7.2[c]	5.7 ± 3.3	<0.001
Vigorous PA	5.9 ± 7.4	10.3 ± 9.4[a,b]	7.0 ± 8.4[c]	3.9 ± 5.0	<0.001
MVPA	13.8 ± 10.9	22.1 ± 12.8[a,b]	16.7 ± 11.3[c]	9.6 ± 7.2	<0.001

[a] $p<0.05$ AT only versus AT+MT; [b] $p<0.05$ AT only versus MT only; [c] $p<0.05$ AT+MT versus MT only

PA: physical activity; MVPA: moderate-to-vigorous physical activity

Table 7. Physical activity in an hour after school (3 pm - 4 pm) across three transport groups

	Total sample (n= 314)	Active transport only (AT only) (n= 73)	Active and motorized transport (AT+MT) (n= 56)	Motorized transport only (MT only) (n= 185)	p-value
Average activity in an hour after school (3 pm - 4pm) (min)					
Sedentary activities	32.1 ± 8.0	30.2 ± 8.1[b]	30.7 ± 8.0	33.3 ± 7.9	0.007
Light PA	17.8 ± 5.6	16.3 ± 5.4[a]	19.0 ± 5.7	18.0 ± 5.6	0.020
Moderate PA	5.6 ± 3.7	7.0 ± 4.4[b]	6.1 ± 3.7	4.8 ± 3.2	<0.001
Vigorous PA	4.2 ± 3.6	6.3 ± 4.9[a,b]	3.8 ± 2.8	3.6 ± 2.9	<0.001
MVPA	9.8 ± 5.8	13.3 ± 6.4[a,b]	9.9 ± 5.3	8.4 ± 5.1	<0.001
Wear and non-wear times (min)					
Wear time	59.7 ± 0.3	59.7 ± 0.3	59.6 ± 0.4	59.7 ± 0.2	0.111
Non-wear time	0.0 ± 0.2	0.1 ± 0.3	0.1 ± 0.4	0.0 ± 0.1	0.151
Percent of wear time (%)					
Sedentary activities	53.8 ± 13.4	50.5 ± 13.5[b]	51.5 ± 13.4	55.8 ± 13.1	0.006
Light PA	29.8 ± 9.4	27.3 ± 9.0[a]	31.8 ± 9.7	30.2 ± 9.4	0.018
Moderate PA	9.3 ± 6.2	11.7 ± 7.3[b]	10.2 ± 6.3	8.1 ± 5.3	<0.001
Vigorous PA	7.1 ± 6.1	10.5 ± 8.1[a,b]	6.4 ± 4.7	6.0 ± 4.9	<0.001
MVPA	16.4 ± 9.7	22.2 ± 10.7[a,b]	16.7 ± 8.8	14.1 ± 8.5	<0.001

[a] p<0.05 AT only versus AT+MT; [b] p<0.05 AT only versus MT only; [c] p<0.05 AT+MT versus MT only

PA: physical activity; MVPA: moderate-to-vigorous physical activity

Table 8. Physical activity late after school (4 pm - 8 pm) across three transport groups

	Total sample (n= 314)	Active transport only (AT only) (n= 73)	Active and motorized transport (AT+MT) (n= 56)	Motorized transport only (MT only) (n= 185)	p-value
Average activity late after school (4 pm - 8 pm) (min)					
Sedentary activities	165.8 ± 23.9	169.1 ± 24.9	161.9 ± 23.3	165.6 ± 23.7	0.263
Light PA	55.8 ± 17.7	53.8 ± 19.0	57.5 ± 18.7	56.2 ± 16.9	0.496
Moderate PA	8.4 ± 4.9	7.9 ± 5.2	9.6 ± 5.2	8.3 ± 4.7	0.139
Vigorous PA	6.5 ± 6.8	6.3 ± 5.7	7.1 ± 8.8	6.5 ± 6.6	0.798
MVPA	15.0 ± 10.3	14.2 ± 9.5	16.7 ± 11.9	14.8 ± 10.1	0.377
Wear and non-wear times (min)					
Wear time	236.6 ± 5.9	237.1 ± 4.8	236.1 ± 5.9	236.5 ± 6.2	0.641
Non-wear time	2.5 ± 5.9	2.1 ± 4.8	3.0 ± 5.9	2.6 ± 6.3	0.694
Percent of wear time (%)					
Sedentary activities	70.1 ± 10.0	71.3 ± 10.4	68.7 ± 10.4	70.0 ± 9.8	0.353
Light PA	23.6 ± 7.4	22.7 ± 8.0	24.3 ± 7.8	23.8 ± 7.1	0.463
Moderate PA	3.6 ± 2.1	3.3 ± 2.2	4.1 ± 2.2	3.5 ± 2.0	0.143
Vigorous PA	2.8 ± 2.9	2.7 ± 2.4	3.0 ± 3.7	2.7 ± 2.8	0.804
MVPA	6.3 ± 4.3	6.0 ± 4.0	7.1 ± 5.0	6.3 ± 4.3	0.385

[a] p<0.05 AT only versus AT+MT; [b] p<0.05 AT only versus MT only; [c] p<0.05 AT+MT versus MT only

PA: physical activity; MVPA: moderate-to-vigorous physical activity

4.2 Transport to School, Physical Activity and Weight Status in Adolescents

For the secondary purpose of this study, adolescents were categorised into different weight status groups based on the age- and gender-specific cut points (Cole et al., 2000), as described in the Methods section. PA and transport to school habits were compared between the different weight status groups. In this section, weight status was categorised into two groups: “underweight or healthy weight” and “overweight or obese”.

4.2.1 Sociodemographic Characteristics of “Underweight or Healthy Weight” Compared to “Overweight or Obese” Adolescents

Overall, 73.2% of adolescents in the present study were categorised as “underweight or healthy weight” and 26.8% were “overweight or obese” (Table 9). The “overweight or obese” group had significantly higher proportion of Māori adolescents compared to the “underweight or healthy weight” group (Table 9). No significant differences were observed in age, gender, neighbourhood deprivation score, distance to school, bicycle and vehicle ownership between the two weight status groups (Table 9).

Significant differences in transport modes to school were observed among the two weight status groups. More than half of adolescents in both weight status groups used MT only to school (Figure 5). In the “underweight or healthy weight” group, approximately one quarter of adolescents used AT only to school compared to approximately one tenth of adolescents in the “overweight and obese” group. Slightly more than one tenth of adolescents in “underweight or healthy weight” group used AT+MT to school compared to about one quarter of adolescents in the “overweight and obese” group (Figure 5).

Table 9. Sociodemographic characteristics by weight status

	Underweight or healthy weight (n= 230)	Overweight or obese (n=84)	p-value
Age (years)	14.7 ± 1.4	14.8 ± 1.5	0.846
Gender [n(%)]			
Males	80 (34.8%)	23 (27.4%)	
Females	150 (65.2%)	61 (72.6%)	0.216
Ethnicity [n(%)]			
New Zealand European	180 (78.3%)	62 (73.8%)	
Māori	9 (3.9%)	13 (15.5%)	
Other	41(17.8%)	9 (10.7%)	0.001
Neighbourhood deprivation score [n(%)]			
1 (least deprived)	69 (30.7%)	28 (33.7%)	
2	57 (25.3)	17 (20.5%)	
3	38 (16.9%)	15 (18.1%)	
4	36 (16.0%)	15 (18.1%)	
5 (most deprived)	25 (11.1%)	8 (9.6%)	0.894
Distance to school (m)	6132 ± 7229	6432 ± 6052	0.736
Number of bikes available to use to get to school [n(%)]			
None	46 (20.0%)	20 (23.8%)	
One	47 (20.4%)	24 (28.6%)	
Two or more	137 (59.6%)	40 (47.6%)	0.151
Number of vehicles at home [n(%)]			
None	8 (3.5%)	0 (0.0%)	
One	64 (27.8%)	21 (25.0%)	
Two or more	158 (68.7%)	63 (75.0%)	0.178

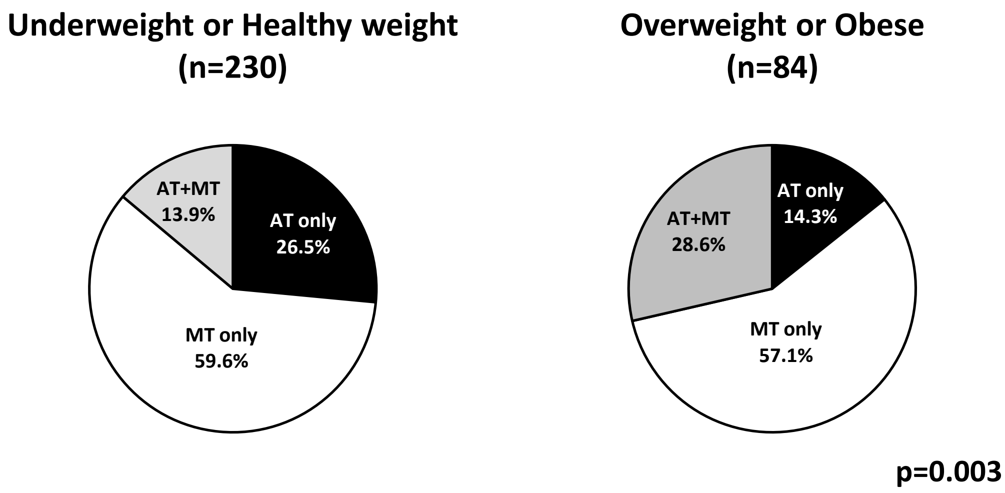

Figure 5. Proportion of adolescents using different modes of school transport by weight status category

AT only: active transport only; AT+MT: active and motorised transport; MT only: motorised transport only

4.2.2 Meeting Physical Activity Guidelines

Higher proportion of adolescents in the "underweight or healthy weight" group (40.9%) met PA guidelines (≥60 minutes of MVPA per day) compared to those in the "overweight or obese" group (34.5%) (Figure 6). No significant differences were observed in weekly, school day and weekend day MVPA between the two groups (Figure 7).

4.2.3 Physical Activity and Weight Status by Transport Modes to School

Adolescents in both "underweight or healthy weight" and "overweight or obese" groups on average accumulated more weekly and school day MVPA compared to weekend MVPA across all three transport groups (Table 10). No interaction was observed between weight status and modes of transport to school on MVPA in adolescents (Table 10).

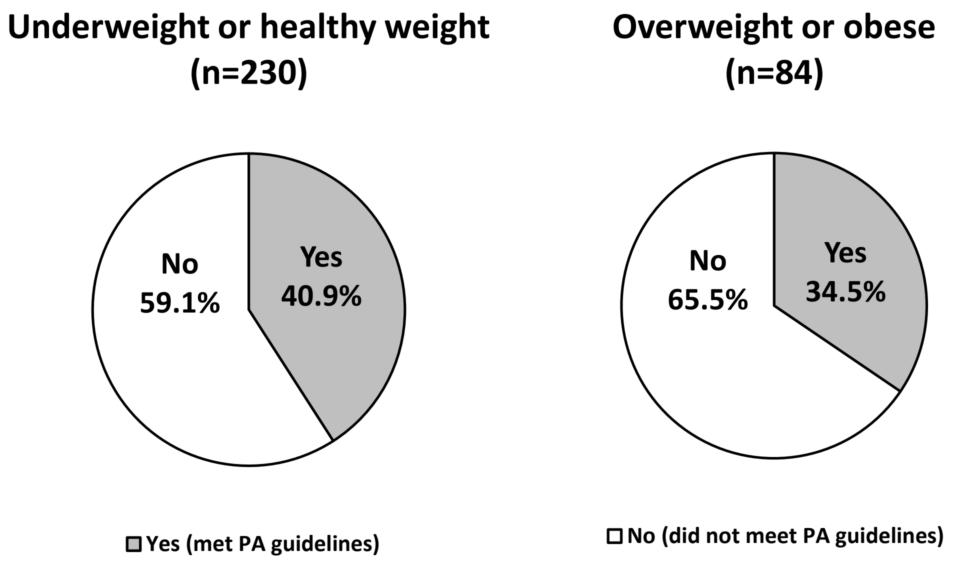

Figure 6. Proportion of adolescents who met physical activity guidelines by weight status category

PA: physical activity

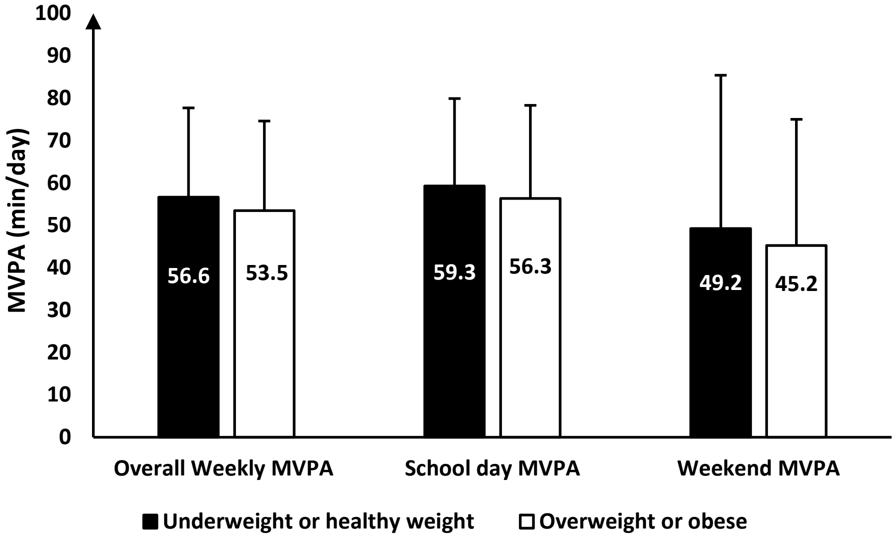

Figure 7. Average daily moderate-to-vigorous physical activity throughout the week, on school days and weekend days by weight status category

MVPA: moderate-to-vigorous physical activity

Table 10. The effects of weight status and transport mode on physical activity

	Underweight or normal weight (n= 230)	Overweight or obese (n=84)	Main effect for weight status	Main effect for transport mode	Interaction between weight status by transport mode
Weekly MVPA (min/day)					
AT only	62.0 ± 23.2	57.7 ± 23.6			
AT+MT	63.1 ± 21.9	55.0 ± 21.0			
MT only	52.8 ± 19.2	51.8 ± 20.7	0.154	0.037	0.557
School day MVPA (min/day)					
AT only	66.1 ± 22.4	61.3 ± 22.9			
AT+MT	67.5 ± 21.8	57.4 ± 21.0			
MT only	54.3 ± 17.9	54.5 ± 22.6	0.106	0.007	0.267
Weekend MVPA (min/day)					
AT only	50.8 ± 35.3	51.7 ± 41.7			
AT+MT	50.1 ± 40.8	47.3 ± 29.0			
MT only	48.3 ± 35.7	42.5 ± 27.1	0.621	0.600	0.854

AT only: active transport only; AT+MT: active and motorised transport; MT only: motorised transport only; MVPA: moderate-to-vigorous physical activity

CHAPTER 5

5 Discussion

This study examined the effects of AT only, AT+MT and MT only to school on PA and weight status in Dunedin adolescents. This study is one of the few studies that assessed objectively-measured PA in adolescents during their commute to school (before and after school hours) across different transport modes and had differentiated AT only, MT only and a combination of AT and MT to school. Key findings of the present study are: 1) nearly half of the adolescents in AT only and AT+MT groups met minimum PA guidelines compared to one third of adolescents in MT only group; 2) AT only and AT+MT groups accumulated higher levels of daily MVPA compared to MT only group on school days but not on weekend days; and 3) AT only group accumulated more MVPA in an hour before (8 am to 9 am) and after (3 pm to 4 pm) school compared to AT+MT and MT only groups whereas no difference was observed in MVPA accumulated during late after school hours (4 pm to 8 pm); 4) no interaction was observed between weight status and modes of transport to school on MVPA in adolescents. 5) on average, Dunedin adolescents spent 9.6 hours in sedentary activities per day, 3.2 hours in light intensity PA per day and approximately one hour in MVPA per day with 39% of adolescents meeting the minimum PA guidelines ($\geq$ 60 minutes of MVPA per day). These findings add further evidence that using AT only but also a combination of AT+MT as modes of transport to school contribute to higher levels of PA in adolescents compared to MT only to school. Using AT to school either alone or in combination with MT increases opportunities for PA in adolescents and increases the likelihood of adolescents meeting recommended PA guidelines ($\geq$60 minutes of MVPA per day) to achieve optimal health. Therefore, in addition to promoting AT only to school in adolescents, future interventions should also promote AT+MT when AT only is not feasible as an alternative to MT only. In addition, other PA opportunities should be encouraged in adolescents on school days during late after school hours and on weekends.

5.1 Transport to School Habits and Physical Activity

In the present study, nearly half of adolescents who used AT only and AT+MT to school met minimum PA guidelines compared to one third who used MT only to school. Previous studies have reported higher proportions of adolescents meeting recommended daily PA (Chillón et al., 2010; Roth et al., 2012) and step count threshold (Abbott et al., 2009) with higher levels of accumulated MVPA or daily step counts in AT users compared to MT users to school. However, the previous studies (Abbott et al., 2009; Chillón et al., 2010; Roth et al., 2012) had assessed commonly used transport to school (AT only versus MT only) and did not examine PA levels in adolescents using AT+MT to school. In the present study, a similar proportion (~50%) of adolescents who used AT only and AT+MT to school met minimum PA guidelines, suggesting that a combined active and motorised transport to school could also provide additional PA opportunities to adolescent as much as using AT only to school. Taken together, these findings suggest that both AT only and AT+MT to school are potential avenues to increase daily PA in adolescents. Therefore, future interventions need to include strategies to encourage adolescents to use AT only and AT+MT to school as an alternative to MT only to increase their PA levels. Specific initiatives could include initiating walking or cycling groups to school or giving credits or acknowledgement to AT only or AT+MT users as part of their physical education achievement.

In the present study, adolescents who used AT only to school accumulated greater amount of average MVPA throughout the week (61.2 minutes per day) compared to those who used MT only to school (52.5 minutes per day). Most previous studies that measured adolescents' PA objectively using accelerometers reported higher overall daily MVPA

(Alexander et al., 2005; Chillón et al., 2011; Chillón et al., 2010; Cooper et al., 2006a; Larouche et al., 2014), step counts (Abbott et al., 2009) and energy expenditure (Tudor-Locke et al., 2003) in AT users compared to MT users to school. In contrast to most previous studies, one study reported no association between AT to school and MVPA in adolescents (Nilsson et al., 2009a). The authors of that study suggested that the differences in MVPA cut-points measured using accelerometers in previous studies could have resulted in the differences observed between findings from those previous studies and their study (Nilsson et al., 2009a).

The present study revealed that combined AT+MT to school also provided the opportunity for higher levels of adolescents' PA compared to the use of MT only to school. In the present study, adolescents who used AT+MT accumulated more MVPA per day (7.1 minutes per day) compared to those who used MT to school throughout the week. Most previous studies (Alexander et al., 2005; Chillón et al., 2011; Chillón et al., 2010; Cooper et al., 2006a; Mendoza et al., 2011) that measured PA objectively in adolescents compared PA levels in AT users versus MT users and did not examine separately PA levels in adolescents who used AT+MT to school. In those studies, data on transport modes to school were collected based on AT only and MT only and no information were reported for adolescents using a combined mode of transport (AT+MT) (Alexander et al., 2005; Chillón et al., 2011; Chillón et al., 2010; Cooper et al., 2006a; Mendoza et al., 2011). Only one previous study reported PA levels in adolescents who used AT+MT to school (Tudor-Locke et al., 2003). In that study, male adolescents who walked to school (AT only) or used a combined active and motorised transport (walking and MT) to school achieved greater daily energy expenditure compared to MT users (Tudor-Locke et al., 2003). However, adolescents in that study wore accelerometers for 24 hours only (Tudor-Locke et al., 2003). A single day of PA monitoring may not provide accurate representation of average daily PA in adolescents (Riddoch et al., 2004; Trost et al., 2000). In the present study, adolescents wore accelerometers for 7 consecutive days and had accelerometer data of at least 3 valid week days and 1 valid weekend day which provided reliable measurements of PA to account for differences between week days and weekend days (Corder et al., 2008; Riddoch et al., 2004; Trost et al., 2000). Findings from the present study provided further support for findings reported by Tudor-Locke et al. (2003). Taken together, those findings suggest that AT+MT could potentially be an alternative transport mode to MT only when AT only is not feasible, contributing to more PA in adolescents. Therefore, future interventions should include strategies for encouraging AT+MT in adolescents for whom AT only to school is not feasible. For example, future interventions could include designing safe drop-off and pick-up points away from school for MT users (using both private and public MT) to walk a short distance to school. In addition, future interventions should promote the use of public transport to school as an alternative to MT only to school. For example, public transport use could be encouraged by providing student concessions for public transport when AT to school is not feasible (i.e., when distance to school poses a barrier for active commuting). To address the current knowledge gap in this area, future studies assessing transport to school should inquire about the use of combined AT+MT in adolescents and should examine PA levels in adolescents using combined AT+MT in addition to AT only and MT only transport modes.

5.2 School Day and Weekend Day Physical Activity

In the present study, adolescents accumulated a greater amount of MVPA on school days (approximately 58.5 minutes per day) compared to weekend days (48.1 minutes per day). Similar findings were reported in American (school day: 49 minutes per day vs weekend: 35 minutes per day) (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008), Canadian (school day: 55.8 minutes per day vs weekend: 38.7 minutes per day) (Comte et al., 2013) and Singaporean (school day: 24 minutes per day vs weekend: 8.5 minutes per day) (Ting et al., 2015) adolescents. Therefore, this study provides further evidence that adolescents are more active and engage in more PA during school days compared to weekend days.

In the present study, adolescents who used AT only and AT+MT accumulated more daily MVPA compared to MT only users during school days but not on weekend days. Similar findings were reported from Alexander et al. (2005) who found that higher overall MVPA were achieved by adolescents who walked to school on school days compared to weekend days (Alexander et al., 2005). Similarly, Carver et al. (2011) reported that AT to school in adolescents was associated with more MVPA on school days than on weekend days (Carver et al., 2011). In that study, male and female adolescents (13 to 15 years) accumulated greater amounts of average school day MVPA (males: 65.3 minutes; females: 45.4 minutes) compared to weekend days (males: 45.0 minutes; females: 28.2 minutes) (Carver et al., 2011). That same cohort of adolescents tracked 2 years later (15 to 17 years) reported a similar school day versus weekend MVPA differences (Carver et al., 2011). However, since Carver et al. (2011) examined only AT users (adolescents who walked and cycled to school), no comparisons in school day versus weekend MVPA could be made between AT and MT users (Carver et al., 2011). Pedometer-based studies involving New Zealand adolescents reported greater accumulated steps on school days versus weekend days in AT users compared to MT users (Duncan et al., 2008; Hohepa et al., 2008).

Therefore, this study adds further evidence that adolescents using AT only to school accumulate greater amount of MVPA and accumulated steps on a school day compared to their peers who rely on MT only to school. Given the lower levels of MVPA accumulated by adolescents on weekend days compared to school days (Alexander et al., 2005; Carver et al., 2011; Nilsson et al., 2009b), strategies to increase PA on weekend days could be implemented to ensure that adolescents achieve consistent amount of PA throughout the week. Future interventions should provide more family- and/or community-based PA opportunities such as learning new games skills that involve PA, participation in community sports events or organised family outings (outdoor trekking, cycling or camping activities) to encourage adolescents to engage in PA during weekends. Therefore, more opportunities for supplementary PA would allow adolescents to accumulate more PA and meet at least minimum PA guidelines on a daily basis to gain health benefits.

5.3 Before and after School Physical Activity

Adolescents' PA levels vary throughout the school day depending on a range of PA offered during school time and after school time. Adolescents who use AT to school generally are active during school commute times (immediately before and immediately after school) as AT to school occurs during this particular period. In the present study, adolescents who used AT only to school accumulated significantly more MVPA in an hour before (8 am to 9 am) and an hour after (3 pm to 4 pm) school compared to those who used AT+MT and MT only. Differences between MVPA accumulated during school commute times accounted for the respective total PA differences during the school day across the transport groups. AT only group accumulated 39.8% of the total school day MVPA during school commute periods (8 am to 9 am and 3 pm to 4 pm) compared to 31.2% and 25.7% of MVPA in AT+MT and MT only groups, respectively. Previous studies have found that AT during school commute times contributed to greater amount of daily MVPA compared to MT to school in adolescents (Mendoza et al., 2011; Saksvig et al., 2007; Saksvig et al., 2012). Saksvig et al. (2007) reported significantly greater average MVPA before (2.5 minutes more) and after (2.2 minutes more) school hours in female adolescents who walked to school compared to non-walkers (Saksvig et al., 2007). Similar results were reported by the same research group in a subsequent study of the same cohort of adolescents 2 years later (Saksvig et al., 2012). Similarly, Mendoza et al. (2011) reported that AT to school was positively associated with greater amount of time spent in MVPA before and after school in American adolescents (Mendoza et al., 2011). Longer periods of time allocated for the before school period (~2 to 2.5 hours) and after school period (~1.5 to 2 hours) in two previous studies (Mendoza et al., 2011; Saksvig et al., 2007) compared to the present study (1 hour each for both periods) likely contribute to a greater total amount of adolescents' PA reported during the before and after school periods in those studies, compared to the findings reported in the present study. Hence, the differences in school commute times may limit the comparison of findings between the studies. Nevertheless, findings from the present and previous studies suggest that promoting AT during school commute times (before and after school) would allow adolescents to capitalise on their school journeys to increase daily PA. Although daily contribution of MVPA during school journey seems little, this consistent source of PA could add up to a substantial contribution to adolescents' PA (Gidlow, Cochrane, Davey, & Smith, 2008).

In the present study, no differences in MVPA among the transport groups were observed during late after school hours (4 pm to 8 pm). This could be attributable to the fact that during this period, adolescents left school for the day and returned home or engaged in other extracurricular activities. Although boys were reported to be more active after school compared to girls (Mota, Santos, Guerra, Ribeiro, & Duarte, 2003), the period after school was found to be a critical time for adolescents to engage in MVPA (Mota et al., 2008). In the present study, adolescents accumulated one quarter (15 minutes) of their school day MVPA time (58.5 minutes) between 4 pm to 8 pm. In a previous study, the late afternoon period (3:00 pm - 5.59 pm) during school days was found to contribute to the main bulk of MVPA for less-active female adolescents (Mota et al., 2008). Aibar et al. (2014) found that the time after school (end of formal school hours to midnight) was considered as an important part of the school day for adolescents to achieve more PA as they engaged in greater amount of MVPA during this period compared to during school time (formal school hours) and therefore, could be targeted to increase adolescents' PA (Aibar et al., 2014). In addition, leisure time after school (3pm to 12 am) was found to be an appropriate time to promote PA (Nilsson et al., 2009b). Therefore, late after school period is a crucial time to encourage adolescents to participate in PA. Overall, these findings suggest that future interventions could involve schools in developing programmes and initiatives to increase AT to school during school commute times. In addition, promotion of after-school PA opportunities for adolescents through collaboration among schools, sports councils and community centres to provide affordable and easily accessed sports facilities and equipment as well as offering sports or game activities after school hours within the community (i.e., in schools, community centres or sports hub) could further increase adolescents' overall PA.

5.4 Active Transport to School, Physical Activity and Weight Status

In the present study, no significant associations were observed between adolescents' weekly, school day and weekend day MVPA, weight status and transport modes to school. Similarly, several previous studies reported that AT to school had no significant effect on weight status or body composition (fat mass or BMI) in English (Baig et al., 2009), Portuguese (Mota et al., 2006) and German (Landsberg et al., 2008) adolescents. For example, Baig et al. (2009) reported that walking to school was not significantly associated to healthier weight status in English adolescents of lower socio-economic status (Baig et al., 2009). In addition, Mota et al. (2006) and Landsberg et al. (2008) also reported no significant associations between AT to school and BMI or fat mass in Portuguese (Mota et al., 2006) and German (Landsberg et al., 2008) adolescents.

In contrast, other studies reported positive associations between higher PA levels and healthier weight status in adolescents who used AT compared to MT to school (Larouche et al., 2014; Mendoza et al., 2011; Tudor-Locke et al., 2003). Tudor-Locke et al. (2003) reported that higher energy expenditure was associated with prevention of weight gain in adolescents who used AT to school compared to MT (Tudor-Locke et al., 2003). Mendoza et al. (2011) found that AT users had higher levels of overall daily MVPA and lower levels of body fatness and adiposity compared to MT users to school (Mendoza et al., 2011). In addition, Landsberg et al. (2008) reported significant association between distance to school and fat mass in adolescents (Landsberg et al., 2008). In that study, adolescents who used AT to school and those who travelled longer distances to school using AT had lower levels of fat mass (Landsberg et al., 2008). In one study, adolescents who cycled <1 hour per week had lower total cholesterol and those who cycled ≥1 hour per week had lower BMI, waist circumference and total cholesterol/ high-density lipoprotein ratio compared to non-cyclists in that same study (Larouche et al., 2014). Thus, cycling to school seems to provide greater health benefits in achieving favourable body composition and healthy weight status compared to walking to school. In contrast to the reported positive associations between higher PA levels and healthier weight status in the several studies, one study also reported an unexpected finding of a negative association between the higher PA levels and healthier weight status in adolescents (Larouche et al., 2014). In that study, adolescents who walked <1 hour per week to school had attained lower waist circumference and total cholesterol/high-density lipoprotein ratio compared to those who walked between 1 - 5 hours per week to school (Larouche et al., 2014).

Taken together, inconclusive findings of the previous and present studies suggest that solely depending on AT to school may not be sufficient to have an effect on adolescents' weight status. Other factors such as biological changes during adolescents' pubertal period, presence of obesogenic environment, sleep duration, dietary habits, social and behavioural factors were found to influence obesity in adolescents (Adair, 2008). Therefore, there is a need for more research to further examine the relationship involving AT to school, PA and weight status in adolescents. Future intervention should focus on reducing modifiable behavioural factors such as increasing PA levels and/or reducing sedentary activities in adolescents through encouraging healthier lifestyles (regular participation in PA or sports, increasing leisure time PA, reducing screen time as well as using AT only or AT+MT to school) to promote effective weight management and alleviate the associated adverse health consequences of overweight and obesity in this age group.

5.5 Time Spent in Physical Activity and Sedentary Activities

The recently published 2017 Canadian 24-hour movement guidelines for children and adolescents recommend accumulating ≥60 minutes of MVPA per day and ≤2 hours of sedentary activities per day to ensure an appropriate amount of time spent on PA and sedentary activities to achieve health benefits (Tremblay et al., 2016). Similar recommendations were also provided in the latest New Zealand PA guidelines (Ministry of Health, 2017). On average, Dunedin adolescents were engaged in 55.8 minutes of MVPA per day, which is below the recommended PA guidelines (≥60 minutes of MVPA per day) for children and adolescents (Strong et al., 2005; Tremblay et al., 2016; World Health Organisation, 2011). In addition, approximately 39% of the adolescents in the present study met minimum PA guidelines based on objectively-measured PA. Previous studies have reported that European (Ruiz et al., 2011) and German (Smith et al., 2016) adolescents accumulated less than 60 minutes of MVPA per day when PA was measured using accelerometers. For instance, European adolescents spent approximately 55 minutes per day in MVPA (higher MVPA observed in males versus females) with 41% of adolescents meeting the recommended PA guidelines (Ruiz et al., 2011). German adolescents accumulated less than one hour of MVPA per day (males: 45.5 minutes per day, females: 37.6 minutes per day) with only 1% of adolescents reported to achieve 60 minutes of MVPA every day, based on an average of 6 days of measurement with valid wear days of ≥1 weekend day and ≥3 week days in that study (Smith et al., 2016). From the present and previous findings, less than half of adolescents in those respective studies met PA guidelines with significant differences between the countries. In the present study, more than half of total adolescents were females and that might have contributed to the lower proportion of adolescents meeting PA guidelines as previous research have shown that females engaged in lower levels of PA than males (Chung, Skinner, Steiner, & Perrin, 2012; Cooper et al., 2006a; Jago, Anderson, Baranowski, & Watson, 2005; Mota et al., 2003; Pate et al., 2002; Riddoch et al., 2004; Ruiz et al., 2011; Smith et al., 2016; Trost et al., 2002). Previous studies have found that MVPA in 10 to 13 year-olds consisted mainly of structured sport (37%), AT to school (26%) and unstructured play (24%) (Olds et al., 2011). AT to school contributed to one quarter of total MVPA (Olds et al., 2011), providing a regular and significant source of MVPA in adolescents (Smith et al., 2016). Taken together, these findings suggest that future interventions for promoting PA in adolescents should focus on school-based programmes, encouraging leisure sport activities and the use of AT to school.

In the present study, adolescents spent a large proportion of their time in sedentary activities (inclusive of all types of sedentary activities in addition to screen time). Previous studies that used objectively-measured PA (Matthews et al., 2008; Ruiz et al., 2011; Smith et al., 2016) have reported similar sedentary behaviour patterns in adolescents. European (Ruiz et al., 2011) and German (Smith et al., 2016) adolescents spent approximately 9 to 10 hours per day in sedentary activities. A study involving American adolescents reported that they spent 7.7 hours per day in sedentary activities. However, the accelerometer wear time (13.9 hours) in a study involving American adolescents (Matthews et al., 2008) was approximately 1.5 hours lower compared to other national surveys in the United States, which might have underestimated the amount of sedentary time in American adolescents (Matthews et al., 2008). In contrast, Singaporean adolescents spent an average of approximately 6.2 hours daily in sedentary activities on school days but only 1.8% met the recommended PA guidelines on school days (Ting et al., 2015). Hence, these findings reiterate the issues relating to large amount of time that adolescents spent in sedentary activities and small amount of time spent in MVPA (Salmon & Timperio, 2007). The findings also reflect differences between the countries. Future interventions should focus on developing policies at a national level with the aim of reducing adolescents' sedentary behaviours and increasing their PA levels.

5.6 Significance and Implications of Findings

Promoting PA in adolescents is especially important in view of the current global health concerns of increasing overweight and obesity levels among children and adolescents due to declining PA opportunities and increasing sedentary behaviours in these age groups. Opportunities for PA in adolescents have reduced drastically in the recent years with a significant decline in the rates of AT to school and increasing reliance on MT to school in addition to many other individual, social, environment and policy factors. This reduction in opportunities for adolescents to engage in PA and meet recommended daily PA are resulting in negative impacts on adolescents' health and weight status.

Based on the present findings, encouraging the use of AT only and AT+MT to school in adolescents should be the focus of interventions aimed at improving health and well-being in adolescents. Findings from this study have presented evidence that AT only and AT+MT to school are viable school transport modes to accumulate higher levels of PA compared to MT only to school and contribute to meeting adolescents' daily PA requirements. In addition, the use of AT+MT to school as a better alternative to MT only provides a potential avenue for passive commuters to school to increase their PA levels. The contribution of PA during school commute times (before and after school) also provides a consistent source of daily PA, which could add up to a substantial amount of PA for adolescents. In the present study, before and after school MVPA accounted for 39.8% and 31.2% of the total school day MVPA in AT only and AT+MT groups respectively compared to 25.7% of school day MVPA in MT only group. The present study found no association between the transport modes to school, PA levels and weight status in adolescents, suggesting that AT to school may not be a sufficient stimulus to have substantial effect on adolescents' weight status. However, AT to school should still be advocated and encouraged in adolescents as a regular source of PA on school days, contributing to higher levels of PA and ultimately providing benefits to adolescents' overall health. Future interventions should involve schools and government agencies working together in developing programmes and initiatives to increase AT to school in adolescents during school commute times and promoting the use of public transport to school in adolescents to encourage the use of AT+MT to school if AT only is not feasible.

5.7 Study Strengths

The strengths of this study include the use of objectively-measured PA, differentiated modes of transport to school (AT only, AT+MT and MT only), PA accumulated at school commute times and a large sample size. The use of objectively-measure PA using accelerometers provides valid and accurate measurement of PA (De Vries et al., 2009; Trost, 2007; Vanhees et al., 2005) and determines real time duration and intensity of PA (De Vries et al., 2009; Trost, 2001, 2007; Vanhees et al., 2005). In this study, PA levels in adolescents using transport to school modes with differentiated AT only, MT only and AT+MT groups were examined which provided a more comprehensive examination of adolescents' transport to school behaviours. To date, only one previous study had examined the use of a combined AT+MT to school (Tudor-Locke et al., 2003) and more research is needed in this area. As PA opportunities in adolescents could occur at different times of the school day and studies have found that the morning hours before school was one of the important key periods for accumulation of MVPA (Mota et al., 2003), another strength of this study is comparing the amount of PA accumulated specifically during these periods across different modes of transport to school.

5.8 Study Limitations

Limitations of this study include a cross-sectional study design, limited measurement of cycling-related PA using accelerometers and the participation of predominantly female adolescents. The cross-sectional study design used in this study precludes the possibility of determining casual relationships between PA levels and transport modes to school in adolescents. Although the use of accelerometers limit the detection of PA data derived from cycling (Trost, 2007; Trost et al., 2002; Vanhees et al., 2005), this limitation may not have great impact on the findings in the present study as only a low proportion of Dunedin adolescents cycled to school (2.1%) compared to those who walked to school (50.8%) (Mandic et al., 2017b). In the present study, 67.2% of participants were female adolescents and hence, the findings in this study may not be generalised to male adolescents. Finally, the findings in this study may be not be generalisable to other geographical settings.

5.9 Future Studies

Future studies should consider the use of randomised controlled study design to determine the effectiveness of AT to school to increase PA levels in adolescents. In addition, future studies should examine the effects of using different modes of transport to school, including combined AT+MT, on adolescents' PA levels in different geographical settings and should include both male and female adolescents to examine potential gender differences. Further studies should examine the association of AT to school, PA and weight status in adolescents, in a larger sample of adolescents and with the inclusion of relevant variables such as dietary intake and other PA activities. Associations between AT, PA and weight status in adolescents from other geographical settings should also be examined to allow for a more comprehensive comparison of findings across different countries.

5.10 Conclusion

In conclusion, nearly half of Dunedin adolescents who used AT only and AT+MT to school met minimum PA guidelines compared to one third of those who used MT only to school. On school days and during school commute times (before and after school), adolescents who used AT only and AT+MT to school accumulated greater amounts of MVPA compared to those who used MT only to school. No differences in MVPA were observed among the three transport groups on school day late after school hours or on weekend days. Finally, no associations were found between adolescents' MVPA (weekly, school days and weekend days) and weight status across the three school transport modes.

The findings in this study presented further evidence that adolescents who used AT only to school achieved higher levels of PA compared to those who used MT only to school throughout the week and on school days. During the school commute times, AT only and

AT+MT users accumulated more minutes of MVPA than MT only users. During the 2-hour school commute time (to and from school), AT only and AT+MT groups spent 26.0 minutes (approximately 22%) and 19.7 minutes (approximately 17%) respectively in MVPA. Therefore future AT promotion initiatives should be complemented by other PA opportunities for adolescents. Higher levels of MVPA and compliance with minimum PA guidelines among adolescents who used AT+MT to school compared to those who relied solely on MT only were also observed. These findings have significant implications for promoting the use of public transport to school among adolescents as well as implementing policies and programs that would encourage combining AT and MT to school when AT only is not feasible. Finally, no interaction was observed between the weight status and modes of transport to school on MVPA in adolescents. Other relevant factors (e.g. lifestyle factors such as dietary habits, screen time, participation in PA, and sleep patterns) should also be taken into account when examining the relationship between transport to school modes, PA and weight status in adolescents due to the complexity of the relationship between these variables.

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APPENDIX

Appendix A: BEATS Study Ethics Approval Letter

UNIVERSITY OF OTAGO
NEW ZEALAND

13/203

Academic Services
Manager, Academic Committees, Mr Gary Witte

19 July 2013

Dr S Mandic
School of Physical Education, Sport and Exercise Sciences
Division of Sciences
46 Union Street West

Dear Dr Mandic,

I am writing to let you know that, at its recent meeting, the Ethics Committee considered your proposal entitled "**Built Environment and Active Transport to School: BEATS Study**".

As a result of that consideration, the current status of your proposal is:- **Approved**

For your future reference, the Ethics Committee's reference code for this project is:- **13/203**.

The comments and views expressed by the Ethics Committee concerning your proposal are as follows:-

While approving the application, the Committee would be grateful if you would respond to the following:

The Committee would be grateful if you could clarify the phasing of this project (students, teachers, parents), and whether the Committee is being asked to approve all phases or just Phase 1.

Please provide an indication of the time involved in participation into the Information Sheets.

In the letter to School Principals, please correct the numbers provided in the paragraph under "What will the Study Involve?" e.g. 150-200 students per school and 80-100 parents per school.

Please provide the Committee with copies of the updated documents, if changes have been necessary.

Approval is for up to three years from the date of this letter. If this project has not been completed within three years from the date of this letter, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Professor D G Booth Dean School of Physical Education, Sport and Exercise Sciences

Appendix B: BEATS Student Survey - Parent/Guardian Information Sheet (Opt-out Consent)

Please read and keep this sheet *

Reference number: 13/203; July 2013

Built Environment and Active Transport to School: BEATS Student Survey

Parent/Guardian Information Sheet

What is the study about?

School-age students are becoming more sedentary. The lack of physical activity in adolescents increases risks of health problems such as obesity, diabetes and heart disease both in teenage years and in adult life. Active transport to school is an effective way to increase physical activity in youth. However, to date we know little about the adolescents' perceptions of active transport to school. It is very important that we learn more about factors that influence active transport and level of physical activity in adolescents, in order to be able to prevent health problems later in life. The aim of this study is to assess transport to school habits, the neighbourhood environment and physical activity of students aged 13 to 18 years in Dunedin.

Why my son/daughter?

We have invited all Dunedin Secondary Schools to take part in this study. Your son/daughter's school has decided to take part in this study and have allowed us to invite all students in your son/daughter's class to participate. All students, however, can individually decide whether or not to take part in the study.

Where will this study take place?

We have agreed with the school principal that the study will take place at school during 2014/2015. Trained researchers will visit the school to conduct the study. The study will be organised to cause minimum disruption to your son/daughter's education.

What will the study involve for your son/daughter?

The trained researcher would like to collect the following information during one school hour:

- **Study questionnaire:** Students will be asked to complete an online questionnaire about their transport to school and neighbourhood environment and draw a map of their route to school. The survey questions are **not like a school test, there are no right or wrong answers** and your son/daughter **does not have to answer** every question if they do not want to. Teachers will be present, but our research team will assist your son/daughter to complete the questionnaire if necessary. All survey participants will be entered in a draw for one of up to five $15 movie vouchers per school.
- **Physical assessment:** Trained research staff will measure students' height, weight and waist circumference in a screened off area of the class. Students will wear light clothing.
- **Physical activity assessment** (optional): Students may also choose to wear a small activity meter (the size is a little larger than an iPod shuffle) on their hip for 7 days after the survey. Research staff will show students how to put on and take off the meter. Participants will receive a log to record the times when they are wearing the monitor. We will collect all devices from your son/daughter's school one week later. Nobody, not even the student, will be able to see the data. Student will receive a $5 book voucher for returning the meter and completed log to their school on a scheduled date and an additional $5 book voucher if wearing the meter for 7 days for at least 12 hours per day.

- **Focus group** (optional): At each school, several students may also choose to participate in a 45-60-minute focus group at their school. In a focus group, students will talk to other group members about their perceptions of walking and cycling to school. All Focus Group participants will receive a $10 book voucher as a gift for their participation.

What will researchers do with the collected data?
Each student's personal information will be collected on a separate paper form and this will be kept separate from the information we collect during the study. The anonymous information from all the questionnaires will be sent to the University web server and only the researchers involved in the project will have access to the data. The data collected will be summarised, presented to policy makers, and reported in research journals. At the end of the study the overall results will be available to students and parents who take part. We will also supply a summary of average findings to the school principal of each participating school. No personal information about individual students will be reported.

What do I do now?
We very much hope that your son/daughter will be able to take part in the BEATS Study. Please discuss the study with your son/daughter. Students can choose not to take part, or they can withdraw from the study at any time. This will not affect their future education or care in any way. Non-participating students will be given class work to do during the study assessments.

- **If your son/daughter is under 16 years of age, you have an option to sign the enclosed parental opt-out consent form** if you do **not** wish your son/daughter to participate in this study. Please **give** the signed parental opt-out consent **to your son/daughter to return to school** as soon as possible.
- Alternatively, you can provide your parental opt-out consent online using the following link: http://www.otago.ac.nz/beats/participants/parents/student-survey (password: bstudentp)

- **If your son/daughter is 16 years of age or older:** Parental consent is not required for students 16 years of age or older. Your son/daughter can choose whether or not to take part.

Who can tell me more about the study?
You can find more information about the study on our website: http://www.otago.ac.nz/beats

If you have any questions about this project, please contact the study coordinator:

Ashley Mountfort
School of Physical Education, Sport and Exercise Sciences, University of Otago, PO Box 56, Dunedin 9054; Phone: 03 479 9112; E-mail: beats@otago.ac.nz

We thank you for your time and hope that you and your son/daughter will be able to take part in the BEATS Study.

Dr Sandy Mandic, Principal Investigator
School of Physical Education, Sport and Exercise Sciences, University of Otago

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix C: BEATS Student Survey - Parent/Guardian Consent Form (Opt-out Consent)

Please sign and return this sheet to your son's/daughter's school reception *

Reference number: 13/203; July 2013

Built Environment and Active Transport to School:
BEATS Student Survey

Parent/Guardian Reply Slip
(Required ONLY for Students under 16 Years of Age)

Thank you for reading the information about the BEATS Student Survey. Please ask us if there is anything that is not clear or if you would like more information.

If you do **not** wish your son/daughter to take part then please fill in the details below and return to your son/daughter's school.

☐ NO, I do NOT wish my son/daughter to take part in the study.

Alternatively, you can complete your reply slip online using the following link:
http://www.otago.ac.nz/beats/participants/parents/student-survey (password: bstudentp)

Name of your son/daughter	School Name	Year at school

Name of parent/guardian (*please print*)	Signature of parent/guardian	Date

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Please give this signed consent to your son/daughter to return to school as soon as possible.
Alternatively, you can provide your consent online using the information provided above.

Appendix D: BEATS Student Survey - Student Information Pamphlet (Opt-out Consent)

UNIVERSITY OTAGO NEW ZEALAND

Built Environment and Active Transport to School:

BEATS Student Survey

BEATS

BEATS Research Team
University of Otago

Contact details:
www.otago.ac.nz/beats
E-mail: beats@otago.ac.nz
Tel: (03) 479 9112

Why are we doing this study?

This is a study looking at:

- How you get to and from school,
- Your opinion about walking or cycling to school,
- What your neighbourhood is like,
- How much physical activity you do.

We hope you will be able to take part if approached by your school.

The results of the study will help to make you and all students in New Zealand healthier and safer.

Why you?

This study is looking for Dunedin students aged between 13 and 18 years and that includes you.

You do not have to take part, but if you do it will be a great help.

Ethics Reference number: 13/203; July 2013

What would you have to do?

If you decide to take part, you will:

- Complete an online questionnaire
- Draw a map of your route to school
- Have your height, weight and waist circumference measured.

This will be completed **at your school** during **one school period**.

We will ask you to take off only your jacket and shoes in a screened off area. Only researchers will see your data.

OPTIONAL:

- Wear a small activity meter for 7 days (the size is a little larger than an iPod shuffle). Nobody, not even you, will be able to see the data. See additional information for details.
- Participate in one 45-60 minute focus group at your school. You will talk to other group members about your perceptions of walking and cycling to school.

Please keep this pamphlet for your records

What do you and your school get in return?

- All survey participants will be entered in a draw for one of up to five $15 movie vouchers per school.
- Activity meter participants will get a graph of their activity for 1 day and may receive up to $10 book voucher *(See additional information for details)*
- All focus group participants will receive a $10 book voucher.
- Each school will receive a $50 book voucher and report with averages for all students.

Where do I get more information?

Study information for students:
http://www.otago.ac.nz/beats/participants/students

Information for parents:
http://www.otago.ac.nz/beats/participants/parents/student-survey

Or contact Ashley Mountfort,
BEATS Project Coordinator
(see contact details on the front page)

What do I do now?

Your Consent:

If you would like to take part, fill out the form on this pamphlet and drop it off at your school reception. We will e-mail you a consent form. Printed consent form will also be available at your school reception.

Alternatively, you can sign your consent online (password: bstudent):

http://www.otago.ac.nz/beats/participants/students

Parental Consent:

IMPORTANT: If you are under 16 years of age, your parent/guardian will have an option to sign parental opt-out consent form if he/she does **not** give you permission to participate.

Your parent can sign his/her opt-out consent online (password: bstudentp):

http://www.otago.ac.nz/beats/participants/parents/student-survey

Students with signed parental opt-out consent will not be able to take part in this study.

Please fill out and return this page

How do I sign up?

If you would like to take part in the BEATS Student Survey, please fill out this form and drop it off at your school reception.

First name: ______

Last name: ______

Phone: ______

E-mail: ______

School: ______

School year: ______

Age: ______

IMPORTANT: If you are under 16 years of age, your parent/guardian will have an option to sign parental opt-out consent if he/she does **not** wish you to take part in this study.

I am interested in taking part in the BEATS Student survey.	☐ Yes	☐ No
I would like to wear an activity meter for 7 days.	☐ Yes	☐ No
I would like to participate in focus group research.	☐ Yes	☐ No

Date: ______

Appendix E: BEATS Student Survey - Student Physical Activity Assessment Pamphlet

Built Environment and Active Transport to School:

BEATS Student Physical Activity Assessment (Optional)

BEATS Research Team
University of Otago

Contact details:
www.otago.ac.nz/beats
E-mail: beats@otago.ac.nz
Tel: (03) 479 9112

BEATS Student Physical Activity Assessment (Optional)

Activity meter

If you do decide to take part, we will ask you to wear a small activity meter (the size is a little larger than an iPod shuffle) for 7 days.

The activity meter will measure your overall activity level. It cannot tell what you are doing or where you are. Nobody, not even you, will be able to see the data.

You will clip the meter to the top of your pants or skirt above your **right** hipbone (either under or above clothing).

You will be asked to wear the activity meter for 7 days for at least 12 hours each day. You will put it on first thing in the morning, keep it on all day (unless swimming or in the water) and take it off right before going to bed.

You will record the times of wearing the monitor in a log. After one week, you will return the meter and log to school. The researchers will send you reminders to return the meter and log.

IMPORTANT

Please note that activity meters are expensive, but have no street value. They do not show you any data, and have short battery life.

You will be asked to take care of the device to prevent damage or loss. **Do not submerge the meter in water.**

Do not let anyone else wear it.

If you are unable to wear the meter for *at least* 12 hours one day, you will be asked to wear it one extra day.

If we see that you did not wear the meter for at least 7 days, for at least 12 hours per day, we may have to send it back for you to wear again.

Rewards:
All participants will receive a graph showing their activity level for 1 day.

You will receive a $5 book voucher for returning the meter and completed log to your school on a scheduled date and an additional $5 book voucher if you wore the meter for 7 days for at least 12 hours per day.

Ethics Reference number: 13/203; July 2013

Appendix F: BEATS Student Survey - Student Consent Form

Please sign and return this sheet to your school reception *

Reference number: 13/203; July 2013

Built Environment and Active Transport to School: BEATS Student Survey

CONSENT FORM FOR STUDENT PARTICIPANTS

Thank you for reading the information sheet for this study. Please ask us if there is anything that is not clear or if you would like more information.

I understand what this study it about. All my questions have been answered in a way that makes sense. I know that:

1. Participation in this study is voluntary, which means that I do not have to take part if I don't want to and nothing will happen to me. I can also stop taking part at any time and don't have to give a reason.
2. Anytime I want to stop, that's okay.
3. If I don't want to answer some of the questions, that's fine.
4. If I have any worries or if I have any other questions, then I can talk about these with the researchers.
5. The computer file with my answers will only be seen by researchers. They will keep whatever I say private.
6. Researchers will write up the results from this study for their University work. The results may also be written up in journals and talked about at conferences. My name will not be on anything that researchers write up or talk about this study.
7. All survey participants will be entered in a draw for one of up to five $15 movie vouchers per school.
8. **Some students will be asked to wear an activity meter for one week. I would like to be included to wear this meter:** ☐ **Yes** ☐ **No** (tick one)
   If you answered "yes", you will be asked to sign an additional consent form at the time of the survey.
9. **Several students will be asked to participate in a Focus Group.** Participants will receive a $10 book voucher as a gift for participation.
   I would like to be included in Focus Group research: ☐ **Yes** ☐ **No** (tick one)

I agree to take part in the study.

………………………………………………………… ……………………………………………

Signed Date

………………………………………………………… ……………………………………………… ………………

PRINT YOUR NAME HERE School name Year at school

Address: ……

E-mail address: …………………………………………………… (required for Focus Group participants)

Are you 16 years of age or older? ☐ Yes ☐ No (If no, your parent may sign a parental opt-out consent on your behalf.)

Appendix G: BEATS Student Survey - Student Physical Activity Assessment Consent Form

Please sign and return this sheet to your school reception

Reference number: 13/203; July 2013

Built Environment and Active Transport to School: BEATS Physical Activity Assessment

Consent Form for Student Participants

I have read the Information Sheet for BEATS Physical Activity Assessment and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in this part of the project is entirely voluntary.
2. I am free to withdraw from the project at any time without any disadvantage.
3. I understand that my participation in this study is confidential and that no material that could identify me will be used in any reports on this study.
4. I agree to wear an activity meter as instructed and take care of it to prevent damage or loss.
5. I understand that the researchers will contact me by e-mail and/or phone to remind me to wear the device during one week and to return the device to school on the scheduled return date.
6. I understand that I may be asked to wear the meter again if I do not wear it for 7 days initially.
7. I agree to return device to my school after 7 days. If I forget to return the device, researchers can contact me or my parents by phone, e-mail or mail to remind me to return the device.
8. I understand that students who return their activity meter and completed log on a scheduled day will receive a $5 book voucher and will receive additional $5 book voucher if they wore the meter for 7 days for at least 12 hours per day.
9. I understand that all students who wear and return their activity meter will receive a graph showing their activity level for 1 day.
10. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand). No personal information about individual participants will be reported.

I agree to take part in the BEATS Physical Activity Assessment:

....

Signed Date

....

PRINT YOUR NAME HERE School name Year at school

Please provide contact details for researchers:

Home address: ____

Home phone number: ___________________ Cell phone number: ____________________

E-mail address: ____