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Validation and Measurement of Physical Activity, Sedentary Behaviour and Active Travel in Second Level Students using Self-Report and Accelerometry

By

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Declaration

I hereby declare that this submission is my own work and that it contains no material previously published or written by another person, nor material which has been accepted for an award in any other university or institute of higher learning, except where due acknowledgement has been made in the text.

Signed: _________________________ Date: ________________________________

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Abstract

Levels of physical inactivity and sedentary behaviour are increasing among adolescents. Measurement of these behaviours is essential in order to monitor prevalence among this cohort. The aim of this research was (i) to measure and examine the physical activity, sedentary behaviour and active travel profile of second level students, (ii) examine the relationship between objective and subjective physical activity measurement methods and (iii) to identify if students who travel actively have more accurate perceptions of distance travelled to school than those who travel by motorised means.

The International Physical Activity Questionnaire for Adolescents IPAQ-A was used to collect self-reported physical activity and active travel behaviour in 13-16 year old adolescents (n=362). Objective physical activity and sedentary behaviour data was gathered in a sub-sample (n=78) using the ActivPAL accelerometer.

According to objectively recorded data, 10.2% of adolescents met the recommended daily guidelines for PA with girls more likely to meet the recommendations than boys (15% and 7% respectively, p=0.357). Adolescent's accelerometer-measured sedentary behaviour averaged 9.6 hours per day. Overall, there were weak to moderate correlations between objective and subjective measurement instruments for both total PA and MVPA. Almost one fifth of respondents walked or cycled to school with a higher proportion of boys than girls commuting actively (27.5 v 15.4%, p=.006). Students who travelled to school by car or bus were more accurate in their estimates of the distance travelled to school than those who travelled on foot or bicycle.

Low levels of physical activity and high levels of sedentary behaviour found in the study highlight the need for interventions to change these behaviours among adolescents. There is an opportunity to increase daily physical activity through the promotion of active travel; levels of which were low in the current study. Objective and subjective measurement methods have their own advantages and the use of both methods, where possible may be the ideal way to assess physical activity and sedentary behaviours.

Chapter One
1.0 Introduction

Physical inactivity is linked with an increase in many non-communicable diseases such as type 2 diabetes, breast and colon cancers, coronary heart disease and reduced life expectancy (Lee et al., 2012). In children and adolescents, obesity is now considered a global health problem (Guo et al., 2012) and has been linked with a decrease in physical activity and increased sedentarism (Layte and McCrory, 2011), perhaps due in part to the higher usage of technology such as smartphones, tablets, computers and gaming in young people. In Ireland, The Irish Health Behaviour in School Aged Children (HBSC) survey (2010) which analysed physical activity participation amongst children and adolescents aged 9-18 years found that just 51% of those surveyed reported exercising four or more time per week (Kelly, Gavin, Molcho, Awobiyi and Nic Gabhainn, 2013). Data from the Children's Sport Participation and Physical Activity Study (CSPPA Study) revealed that 99% of Irish children aged 10-18 spent more than the recommended 120 minutes per day in screen time (Woods, Tannehill, Quinlan, Moyna & Walsh, 2010), which is only one component of sedentary behaviour. Sedentary behaviours among youth have been associated with poor body composition, reduced fitness levels, lower self-esteem and reduced academic achievements (Tremblay et al., 2011). The health benefits of physical activity for adolescents are well documented and participation in regular physical activity during childhood and into adolescence is essential for both current and future health (American Physical Activity Guidelines Advisory Committee, 2008).

1.1 Rationale for the Study

Adolescence is a critical time in the development of good habits such as healthy eating and physical activity, as behaviours at this time have been shown to track into adulthood (Due et al., 2011). Physical activity has been shown to decrease dramatically during adolescence (Troiano et al., 2008). Therefore, it is imperative that interventions to promote physical activity and decrease sedentary behaviour among adolescents are developed. Prior to the development and administration of these interventions, it is important that a) baseline measurements of the current levels of adolescent physical activity and sedentary behaviour are undertaken and b) valid and reliable methods of measurement are developed.

Physical activity can be difficult to measure among children and young people because of the intermittent nature of how it occurs, and therefore there has been an increase in the use of objective measures (Rowlands and Eston, 2007). While questionnaires are suitable for large populations, they are often prone to over-reporting PA participation and under-reporting sedentarism (Prince et al., 2008). Amongst children and young people, issues such as ability to recall, social desirability and other biases can affect self-report (Sirard and Pate, 2001). Therefore, since the early 2000's, there has been a marked increase in the number of studies using accelerometers to measure physical activity in children (Rowlands, 2007). Sedentary behaviour measurement to date has also had its limitations; for example self-report measures have mostly asked about TV viewing time which is only one facet of sedentary behaviour (Dowd et al., 2012). The use of the ActivPAL accelerometer, with its built in inclinometer, allows researchers to examine and measure sedentary behaviour in detail (Dowd et al., 2012). Understanding the patterns of sedentary behaviour, as measured by accelerometry, will assist in the design of interventions that are tailored for specific populations and their sedentary habits. Accurate measurement is also important to track the patterns and changes in sedentary behaviour between and within individuals over time (Atkin et al. 2012). In an Irish context data on sedentary behaviour is scarce.

To date, most studies in Ireland have used self-report methods to evaluate physical activity and sedentary behaviour in young people (Woods et al., 2010; Kelly et al., 2013). The use of objective methods to measure physical activity and sedentary behaviour allow for a greater understanding of the habitual patterns of these behaviours. They also provide a measure of validity for the questionnaire assessment of physical activity. Until now, no studies have examined the correlation between the IPAQ-A and ActivPAL accelerometers in an adolescent population in Ireland. There is a need for the accumulation of accurate data regarding physical activity and sedentary behaviour among Irish adolescents and the results of the current study may provide valuable information on these behaviours for future studies and intervention strategies. Therefore, the overall aim of this study is to examine adolescent's physical activity and sedentary behaviour levels using both objective and subjective measurement methods.

1.2. Research Questions

a) What is the physical activity profile, and sedentary behaviour profile of school-going male and female adolescents?
b) Is there a relationship between data collected objectively using the ActivPAL accelerometer and subjective data collection using the IPAQ-A questionnaire in school-going adolescents?
c) What is the active travel profile of second-level students?
d) Do active commuters and non-active commuters have accurate perceptions of travel distance to school?

1.3 Structure of Thesis

Chapter 2 reviews the literature on physical activity (PA) levels and the associated benefits of PA, correlates of adolescent PA, methods of PA measurement, sedentary behaviour (SB) prevalence, correlates and measurement of SB, and the prevalence and benefits of active travel. Evidence surrounding the use of objective measurement of activity, specifically accelerometers, will also be addressed. The methodology employed will be outlined in Chapter 3 while the study findings will be presented in detail in Chapter 4. Discussion and interpretation of the results will be contained in Chapter 5. The final chapter will draw conclusions and propose recommendations for future research and interventions.

Chapter Two

2.0 Literature Review

2.1 Physical Activity and Health

The WHO Global Recommendations on Physical Activity for Health (2010) report that the fourth highest risk factor for mortality worldwide is physical inactivity. The WHO estimated that the rate of physical inactivity was 31% globally among people over the age of 15 in 2008 (WHO, 2014). Lee et al. (2012) postulate that a reduction and/or removal of physical inactivity could significantly improve health worldwide. Using population attributable fractions (PAFs), which are used in epidemiology to estimate the effect of risk factors on the incidence of disease in a population, Lee and colleagues reported that worldwide, if all inactive people became active, there would be a decrease of all-cause mortality by 9.4%. For Ireland the PAF is even greater at 14.2%.

Evidence is mounting of the importance of physical activity (PA) in maintaining health and preventing disease. The American Physical Activity Guidelines Advisory Committee (2008) rated this evidence as strong or moderate for both children/adolescents and adults/older adults. For adults and older adults there was strong evidence for a number of health benefits of PA such as lower risks of early death, coronary heart disease, stroke, high blood pressure, negative blood lipid profile, type 2 diabetes, metabolic syndrome, colon and breast cancer, along with positive changes in body composition related to weight loss and the prevention of weight gain. There is also moderate evidence of lower risks of hip fracture, lung cancer, endometrial cancer and improved bone density and sleep quality. Similarly, Warburton et al. (2010) in a systematic review of 254 articles found that regular PA has a preventative effect on premature death and the following chronic diseases: cardiovascular disease, stroke, hypertension, colon cancer, breast cancer, type 2 diabetes (diabetes mellitus). They also found evidence to support the positive effects of exercise on bone health thereby reducing the risk for osteoporosis.

Not only has PA been proven to have important physical benefits, many studies have shown that PA is related to mental health. For example, Daley (2008) reported a positive effect of exercise on depression. Similarly, Goodrich and Kilbourne (2010) reported anecdotal evidence that patients with bi polar disorder used exercise to help manage their mood symptoms. Asztalos et al. (2009) found that participation in PA, specifically in sport, was linked with less distress amongst middle-aged unemployed adults, and less stress in women and young adults who were unemployed, along with young adults with blue collar jobs. Furthermore, self-esteem and life satisfaction may be increased through the social interaction and support gained through participation in sport and exercise groups (Fox, 1999). PA may also improve cognitive function in older adults (American Physical Activity Guidelines Committee, 2008) along with the possibility of increased mobility, independence and social interaction (Fox, 1999).

2.2 Benefits of PA in Childhood and Adolescence

School-aged children and youth can gain many health benefits from participation in PA (Janssen and LeBlanc, 2010). Those who are physically active, when compared to their inactive counterparts, have been shown to have superior cardiorespiratory fitness, muscular endurance and strength, less body fat, better bone health, and reduced symptoms of both anxiety and depression (WHO, 2010). Strong et al. (2005) in a review of over 850 articles pertaining to PA for school aged youth also found strong evidence to support the positive effects of exercise on health including musculoskeletal health, several components of cardiovascular health, adiposity in youths who are overweight and in the blood pressure of adolescents with mild hypertension.

Hallal, Victora, Azevedo and Wells (2006), in a review of the literature on the effects of adolescent PA on health, proposed a conceptual model of this relationship. The model (*Figure 1)* includes four direct effects (pathways A-D) and three indirect effects (pathways E-G). Pathway A represents the effect of PA in adolescence on adult PA. In this regard, Huotari, Nupponen, Mikkelsson, Laakso and Kujala (2011), in a 25-year population based study, found that PA in adolescence was a significant predictor of PA in adulthood amongst both men and women. Despite this Hallal et al. (2006) had stated that the extent of this relationship is moderate and proposed a number of possible reasons for this such as the fact that PA in adulthood is influenced by a number of other factors, i.e. socio-demographic, environmental, personal and behavioural. It was also suggested within this pathway that methodological issues such as the type of physical fitness measure used in studies, PA measurement techniques, and timing of data collection can affect study results in this Pathway. Pathway B in the model relates to the direct effect of PA during adolescence on adult morbidity. Despite a lack of longitudinal studies in this area, the authors did find consistent long term positive effects of adolescent PA on both bone health and breast cancer in the studies reviewed. Also, the American Physical Activity Guidelines Advisory Committee (2008) stated that young people who are active on a regular basis are more likely to be healthy as adults. This may be due to the fact that while children and adolescents usually don't get chronic diseases such as heart disease, hypertension, osteoporosis, the risk factors for these diseases such as physical inactivity, overweight and obesity can often begin in adolescence, but don't become an apparent health threat until mid-to-late adulthood (Menschik, Ahmed, Alexander and Blum, 2008; Gore et al., 2011). Therefore, regular exercise can reduce the likelihood of these risk factors developing and manifesting as ill health later in life.

The influence of PA in the treatment and prognosis of adolescent morbidity is identified as pathway C. A number of studies in the review showed some positive effects of PA amongst adolescents with certain pathologies. For example, swimming is beneficial in the treatment of asthma; cystic fibrosis patients tend to have improved self-esteem and increased lung function as a result of adolescent PA. The authors, however, concluded that while this pathway is an important part of the conceptual model, PA recommendations for adolescents should be based on healthy subjects rather than unhealthy ones (Hallal et al., 2006).

The final direct pathway (D) is based on the short term influence of PA during adolescence on adolescent morbidity. In their review of the literature, the authors concluded that adolescent PA provides many benefits, in particular in relation to both bone and mental health. A number of studies have similarly linked PA with positive mental health. The results of a study by McPhie and Rawana (2012) showed the beneficial effects of PA on self-esteem and depressive symptoms, thereby highlighting the importance of PA in the maintenance of emotional well-being in adolescents. Also, in a study of 1,446 children aged between 11-14 years, those who participated in at least one hour of activity per day reported less emotional problems when surveyed one year later (Wiles et al., 2008). The indirect pathways contained in the model are present because of the effect that PA in adolescence may have on the risk factors associated with disease in adulthood which may not be detectable or measurable in adolescence (Hallal et al., 2006).

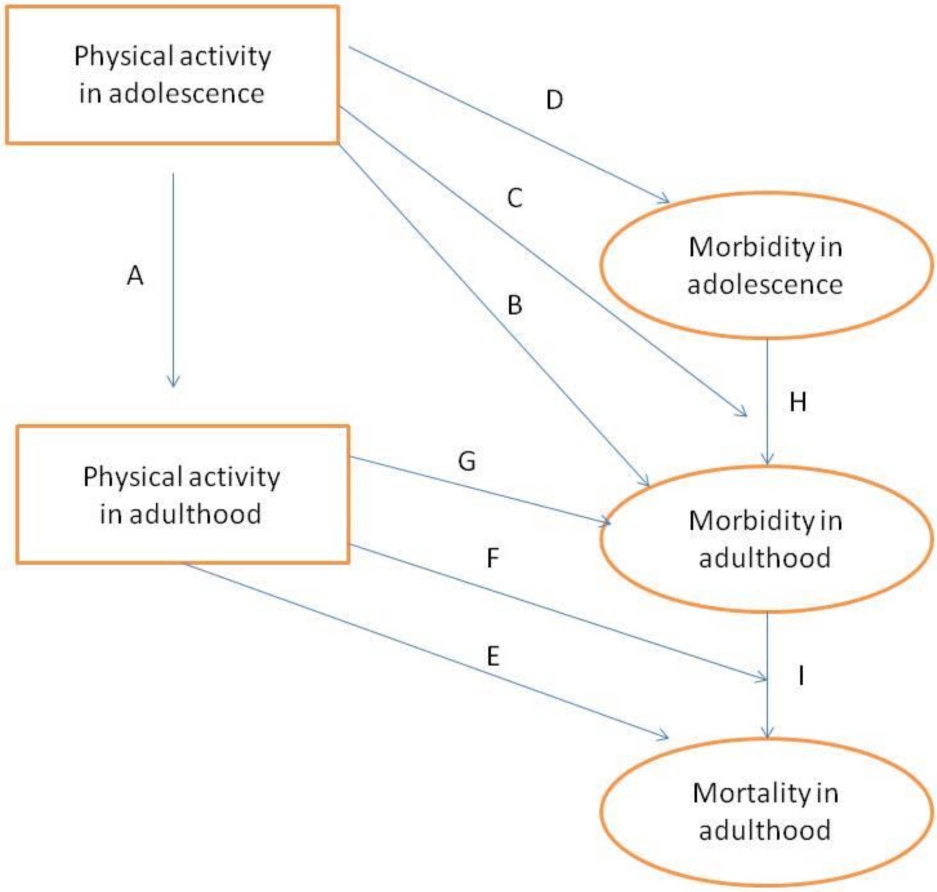

Figure1

Conceptual Model of the relationship of adolescent physical activity on health (Hallal et al., 2006)

Obesity, which is relevant to pathways B, C, and D above, is now considered a global public health problem among children (Guo et al., 2012). According to the World Obesity Federation (2014), up to 200 million school-aged children globally are considered overweight, with between 40-50 million of that figure classified as obese. Among the 27 member states of the EU, 20% (over 12 million) of school aged children are either overweight or obese. Physical inactivity is a major contributing factor to overweight in youths (Strong et al., 2005). Youth with normal weight levels who participate in high levels of PA are more likely to have lower levels of body fat than youths who participate in lower levels (WHO, 2010). As with adults, excess weight in children and adolescents increases the risk factors associated with conditions such as type 2 diabetes and hypertension as well as other problems such as joint abnormalities and sleep disturbances (DeMattia, Lemont and

Meurer, 2006). As a result, the likelihood of overweight/obese adolescents having high blood pressure or high cholesterol by the time they reach young adulthood are 1.5 to two times higher than their counterparts who are not overweight/obese, irrespective of their BMI in young adulthood. Regular exercise can assist with the regulation of percentage body fat in children and adolescents through the reduction in overall body fat and abdominal fat in overweight/obese youth (American Physical Activity Guidelines Advisory Committee, 2008).

2.3 Irish and International Data on Population Physical Activity Levels

The SLAN 2007 survey was the third national Survey of Lifestyle, Attitudes and Nutrition in Ireland. Data were collected from 10,000 participants. In relation to the PA aspect of the survey, over half of those surveyed (55%) reported being physically active - which was defined as partaking in sport or exercise 2-3 times per week for at least 20 minutes each time or doing other activities such as walking, dancing, cycling 4-5 times per week, adding up to at least 30 minutes each day. There was not much difference in PA levels over the three SLAN surveys 1998, 2002 and 2007. For example, those who reported moderate/strenuous exercise 3 or more times per week went from 38% in 1998 to 40% in 2002 and 41% 2007 (Morgan et al., 2008).

In 2007, the International Physical Activity Questionnaire was also used to record PA levels and responses were used to calculate a score based on the following categories; high (over 10,000 steps per day, moderate (between 5,000-10,000 steps per day, and low (i.e. less than 5,000 steps per day). Overall, 47% of respondents scored within the moderate range, 24% were categorised as high, while 29% fell within the low category (Morgan et al., 2008). The SLAN survey was not continued in 2012. The most recent study on Irish Sport and Exercise participation levels, conducted by Ipsos MRBI (2013) found that 32% of adults are sufficiently active (i.e. taking part in 30 minutes of moderate PA at least five times over the previous 7 days), an increase of 2% since the 20011 survey. Sedentarism, which was defined as not participating in more than 20 minutes of recreational activity over the past seven days and did not walk or cycle regularly for transport, also fell from 16% to 13% from 2009. There are no current surveillance data on physical activity in Ireland.

The SLAN study reported a greater number of younger respondents participating in higher levels of PA in comparison to older respondents (Morgan et al., 2008). Similarly, a cross sectional survey undertaken by Livingstone et al. (2001) reported that PA decreased as age increased. In this study, and in the SLAN analysis, it was also apparent that men were significantly more active than women. However, when looking at methods of being active, men were twice as active in occupational and leisure activity while women were three times more active in household tasks (Livingstone et al., 2001). These findings were reiterated in the National Adult Nutrition Survey (NANS) which was completed between 2008 and 2010 and looked at participant (n=1500) behaviours in terms of food and beverage consumption, nutrition intake and PA. Information on PA habits were gathered via self-report questionnaires and accelerometry (Actigraph). Again, men were found to be more active than women in occupational and leisure time activity (1.5 times) while women were 2.5 times more active in household duties. Similar to the aforementioned studies by Morgan et al. (2008) and Livingstone et al. (2001) they found levels of PA to decrease as age increased (Irish Universities Nutrition Alliance, 2011).

In terms of international levels of PA, the Physical Activity Council in the United States track participation in 119 sports and activities yearly. Figures from the 2012 report showed that 68.1 million Americans over the age of six were inactive i.e. did not report participating in any of the activities monitored. This equates to 24%, of the population, which corresponds to an increase of 8% over the previous three years (Physical Activity Council, 2012). Conversely, PA statistics from the British Heart Foundation (2012), found the number of adults meeting current guidelines for PA increased in both England (39%) and Northern Ireland (33%) since 1997 and 2001 respectively (Townsend et al., 2012). Figures from the Scottish Health Survey in 2012 showed that 62% of adults self-reported meeting the MVPA guidelines weekly; this proportion is unchanged from the 2008 survey (Rutherford, Hinchliffe & Sharp, 2013).

2.4 Irish and International Data on Physical Activity Levels of Children and Adolescents

There have been some studies focusing on the PA habits of children in Ireland. Most recently, the *Growing Up in Ireland* study undertaken by the Department of Health and Children (2009), a longitudinal study, is tracking the development of two cohorts of young children for at least 7 years. There are almost 20,000 children taking part in the study. The first publication *The Lives of Nine Year Olds* included information on sport and exercise. Children were asked to report the number of times over the past seven days that they were physically active (at a moderate to vigorous level) for at least 60 minutes. For children, the WHO (2010) recommends that 60 minutes of MVPA daily is required for positive health. A quarter of children (25%) reported engaging in 60 minutes of MVPA daily. Four percent did not meet the guidelines on any day of the previous seven days. Girls were significantly less likely than boys to meet the recommendations (21% versus 29% respectively; Williams et al., 2009). In November 2012, data was published from the second wave of interviews, when the children were 13 (Economic and Social Research Institute, 2012). Approximately 7,400 children were re-interviewed. Results showed that obesity and overweight were on the increase. In terms of PA, approximately 39% of 13-year olds took part in hard or light exercise on at least 9 of the previous 14 days; boys were more likely to exercise frequently than girls (47% vs 31% respectively). A recent study on the baseline data from the 9 year old children examined the associations between screen time, PA and overweight/obesity. Children were classified as engaging in high PA if they met the PA guidelines on 9 or more days of the previous 14. Girls were significantly less likely to be categorised in the high PA group than boys (47% vs. 62%, $p < .05$; Lane, Harrison and Murphy, 2014).

The Children's Sport Participation and Physical Activity Study (CSPPA Study) was undertaken by Woods et al. in 2010. Data were collected via self-report surveys, objective measures of PA (via motion sensors) and qualitative interviews. The cross sectional study involved a total of 9794 children aged between 10 – 18 years along with 103 school administrators and volunteers who provided opportunities to this age group to participate in sport and exercise. Only 19% of primary and 12% of post-primary school children met the guidelines of at least 60 minutes of moderate to vigorous physical activity (MVPA) daily as measured by self report. Those children who did meet the guidelines had the best health profile (i.e. BMI, waist circumference, cardiovascular fitness and blood pressure) of all children. However, out of all participants in the study, one in four were unfit, overweight or obese, or had increased blood pressure.

The Irish Health Behaviour in School Aged Children (HBSC) survey (2010), which is completed every four years, found that there was not much change over time in reported frequency of exercise, PA and inactivity among children aged 9-18 years. In 2006, 53% of children reported exercising four or more times a week; this figure was 51% in 2010. In the same time period there was a 1% (to 9%) decrease in children reporting participation in vigorous exercise less than weekly with 25% of children surveyed responding that they were physically active on 7 days in the last week (down 2% since 2006). The report also found significant differences between genders; 60% of boys and 40% of girls reported exercising four or more time a week. In addition, younger children aged 10-11 years were more likely to report exercising four or more times a week (62%) than adolescents aged 15-17 (41%; Kelly et al., 2013)

The Take PART Study (2004) undertaken by Woods et al. focussed on teenagers (n=939) between the ages of 15-17 years old. The Take PART questionnaire was developed specifically for the study and combined a number of well-known, valid and reliable self-report measures and was used to quantify PA and measure other psycho-social variables. Fitness and health measurements included BMI and the 20metre Shuttle Run Test. The main findings in relation to PA showed that 65% of 15-17 year olds did not meet the approved guidelines for PA. Females reported being significantly less likely to partake in the minimum recommendations for PA in addition to displaying lower levels of estimated aerobic fitness than males.

Internationally, the 2009/2010 HBSC survey, conducted across 43 countries and regions in the World Health Organisation European Region and North America, assessed demographic and social influences on the health of young people aged 11, 13 and 15 years (Currie et al., 2012). Results showed a decline in MVPA with age amongst boys, with a distinct reduction by age 15 in most countries and regions. The results were similar for girls; however, there was a greater decline by age 15. There was also a significant sex difference in MVPA with girls less likely to meet the recommended guidelines of MVPA daily (at least 60 minutes). Other international studies in Europe (De Cocker et al., 2011), Australia (Australian Bureau of Statistics, 2012) and the US (Troiano, Berrigan, Dodd, Mâsse, Tilert and McDowell, 2008) have reported similar findings with younger adolescents reporting more total PA than older adolescents and boys being more active than girls.

While there is a huge range of literature pertaining to the current and future health benefits of PA, there is cause for concern over the numbers of Irish youth meeting the recommended guidelines of PA. There is also consistent evidence that girls participate in less PA than boys and this issue needs to be addressed. A lot of the existing literature is based on self-report methods and therefore may be prone to over-reporting of PA; therefore it is important that future studies aim to include some objective measures, such as accelerometers.

2.5 Adolescent Correlates of Physical Activity

According to Bauman et al. (2012), gaining knowledge of both the correlates (i.e. the factors related to participation in PA) and determinants (i.e. factors with a causal relationship) of PA may help in decreasing physical inactivity. There have been many reviews of the correlates of PA of children and adolescents (Sallis, Prochaska and Taylor, 2000; Gustavson and Rhodes, 2006; NICE Public Health Collaborating Centre for Physical Activity, 2007; Bauman and Bull, 2007; Ferreira et al., 2007; Bauman et al., 2012; Lim and Biddle, 2012). Within these reviews, correlates are typically categorised under the following headings: demographic/biological, psychological/cognitive/emotional, behavioural/skills, social/cultural, and physical environment (Sallis et al., 2000). More recently, policy correlates along with genetics, evolution, and obesity have also been studied as determinants of PA (Bauman et al., 2012).

2.5.1 Demographic/Biological Correlates

Socioeconomic status, ethnicity, age and gender are the typical demographic correlates examined. Sallis et al. (2000) carried out a comprehensive review of 108 studies on the correlates of PA in children and adolescents and found the most consistent finding within this correlate grouping was that boys were more active than girls. Van der Horst et al. (2007) also found that boys were more physically active in their systematic review of 60 relevant studies published between 1999 and 2005. This finding was also supported by a study on the correlates of exercise participation conducted on 300 adolescents by Ammouri et al. (2007).

With regard to the relationship between age and PA, Sallis et al. (2000) found a negative association in 70% of the comparisons undertaken; age was inversely associated with PA. Van der Horst et al. (2007) concluded that the evidence was inconclusive for both age and ethnicity. In their review, Sallis et al. (2000) found that non-Hispanic whites were more active than other ethnic groups while Schmitz et al. (2002) in a study carried out on 3798 adolescents found that the demographic variables of race and SES were among the strongest factors in predicting both PA and sedentary leisure habits.

Studies into the association between socioeconomic status and PA among adolescents has had mixed results. Some reviews of the literature have found no association between SES and PA amongst adolescents (Sallis et al., 2000; Van der Horst et al., 2007). However, more recently, lower family SES was related to persistent inactivity in a longitudinal study conducted by Richards, Poulton, Reeder and Williams (2009) on the childhood correlates associated with participation in PA by adolescents. De Cocker et al. (2012) in a cross sectional analysis of 2780 adolescents aged between 12 – 18 across nine different countries in

Europe found that adolescents from low wealth families reported lower levels of moderate-to-vigorous PA.

The biological correlate most often studied is body mass index (NICE, 2007). Van der Horst et al. (2007) found no association between BMI and PA. Richards et al. (2009) found that inactive adolescents tended to self-report poorer health and had lower cardio-respiratory fitness compared to those considered active; however, they found no link between BMI and patterns of PA.

2.5.2 Psychological/Cognitive/Emotional Correlates

Sallis et al. (2000) found achievement orientation, perceived competence and intention to be active the most consistent psychological variables that were positively linked with PA in adolescents. However, variables such as self-esteem, self-motivation, external locus of control, enjoyment of exercise and perceived stress were all found to have no association with PA, while depression was only factor to be negatively related to adolescent PA. Conversely, Schmitz et al. (2002) found no association between depressive symptoms and adolescents PA levels; however, they were associated with increased sedentary behaviours such as television viewing and/or the playing of video games.

Self-efficacy (i.e. a person's confidence in their ability to be physically active in certain situations) has been found to be a consistently positive correlate and determinant of PA in adolescents (Van der Horst et al., 2007; Bauman et al., 2012). In a study of the relationship between health beliefs, self-efficacy, social support and sedentary activities and PA levels in 10-16 year olds (n=92), Strauss, Rodzilsky, Burack and Colin (2001) found that self-efficacy along with age and sex were independent correlates of intense PA. Similarly, Lee et al. (2010) found self-efficacy to be a positive factor in the participation of both boys and girls in PA while Kim and Cardinal (2010) established that self-efficacy had the strongest effect of all psychosocial variables on Korean adolescents' PA behaviours; those adolescents with high self efficacy were more likely to take part in PA compared to those with lower levels.

2.5.3 Behavioural/Skills Correlates

Sallis and Owen (2002) found previous PA had a positive association with current PA, and this was also reported by Bauman et al. (2012). Sensation seeking, participation in community sport, alcohol use, healthy diet and sedentary time were all reportedly unrelated to PA (Sallis and Owen, 2002) as was smoking (Bauman et al., 2012; Richards et al., 2009; Sallis et al., 2000; Van der Horst et al., 2007). The relationship between PA and sedentary behaviour (SB) is not conclusive. For example, SB out of school time (evenings and weekends) was consistently negatively associated with adolescent PA according to Sallis et al. (2000). Conversely, a cross-sectional study by Marshall et al. (2002) found no negative correlations between PA and SB. This will be addressed further in section 2.6.2.

2.5.4 Social/Cultural Correlates

Family social support was highlighted by Bauman et al. (2012) as one of a small number of variables identified as a consistent correlate of adolescent PA behaviour. Kim and Cardinal (2010), in a study of the psychosocial correlates of Korean adolescents' (n=1347) PA behaviour, found that friend support was the most important relationship of all the social support variables. This is supported by the reviews undertaken by Sallis et al. (2000) and Van der Horst et al. (2007) who found that family influence and support, and friend support, were positively related to adolescent PA participation; although there was no association between actual parental activity and adolescent PA. Gustavson and Rhodes (2006) in their review of the parental correlates of PA in children and early adolescents reported mixed findings in the 14 studies they reviewed. They reported parental PA as a reasonable predictor of children's PA in 6 studies, but in 7 studies little or no relationship was found. However, in terms of parental support for PA, all but one of the studies showed a strong positive relationship between parental support and child PA levels.

2.5.5 Physical Environment Correlates

In their review of literature on the influence of attributes in the physical environment on children's PA, Davison and Lawson (2006) defined the physical environment as "*objective and perceived characteristics of the physical context in which children spend their time (e.g., home, neighbourhood, school) including aspects of urban design (e.g., presence and structure of sidewalks), traffic density and speed, distance to and design of venues for physical activity e.g., playgrounds, parks and school yards), crime, safety and weather conditions".* According to Bauman and Bull (2007), it is only recently that research has been undertaken to examine the environmental correlates of PA in both children and adolescents as heretofore the majority of studies concentrated on adults.

Both Van der Horst et al. (2007) and Ferreira et al. (2007) found no relationship between the availability of facilities and PA among adolescents. However, Davison and Lawson (2006), in a review of the literature including 33 quantitative studies on associations between the physical environment and PA in children aged 3 – 18 years, found significant positive correlations between closeness of playgrounds/parks to the home and availability of recreation areas, and children's PA. Ammouri et al. (2007) using a modified version of the Neighbourhood Environment Scale (which is made up of three distinct subscales: the neighbourhood, perceived safety and home supplies and equipment) found that environmental opportunities for partaking in PA was positively associated with exercise participation in female adolescents. Motl et al. (2007) found that perceived physical environmental factors (i.e. equipment accessibility and neighbourhood safety) had an indirect effect on self-reported PA in adolescent girls. Participation in leisure time sports was associated with the perceived physical environment correlates such as perceived safety from traffic, access to recreational facilities, access to exercise equipment at home and less electronic devices in the bedroom according to Deforche et al. (2010).

Not many studies have examined the effect of location of residence of adolescents in determining PA participation and there does not appear to be an effect of residing in urban versus rural regions, according to Ferreira et al. (2007). Davison and Lawson (2006) found that children are more likely to actively commute to school if the school is in close proximity.

Davison and Lawson (2006) found no association between children's PA and school size. However, the type of school attended (i.e. high school rather than vocational school) has shown to be positively correlated with adolescents exercise participation (Ferreira et al., 2007). The same study also found that the provision of PE classes and/or school sport were unconnected to adolescent PA behaviour. Indeed, Davison and Lawson (2006) found that when the school play areas had certain features such as access to equipment, marked courts, and permanent play structures, children were more active during play times.

Deforche et al. (2010) examined the relationship between perceptions of the social and physical environment and active transport and leisure time sports among Belgian adolescents (n=1445) and found that higher land use mix diversity, higher street connectivity, attractive environments, access to recreational facilities and high emotional satisfaction with the neighbourhood were all positively correlated with active transportation. In their review, Davison and Lawson (2006) found that young people participated in more active transportation when there were sidewalks in the neighbourhood, they had a destination to travel to, access to public transport, less uncontrolled junctions to cross and less traffic.

2.6 Sedentary Behaviour

The traditional focus of research studies into exercise and PA has been on moderate to high intensity activity and not on light intensity or sedentary behaviour (SB). Light PA, which is often classified alongside SB, is actually a distinct category of PA with estimated energy expenditure of between 1.6-2.9 METs and includes activities like slow walking, cooking, and washing dishes (Pate, O'Neill and Lobelo, 2008). SB is the term used to describe activities that do not raise energy expenditure much beyond resting level; for example sleeping, sitting, lying and watching TV and other screen-based activities (Pate et al., 2008). Therefore, SB is not just the absence of activity (Ward et al., 2005).

Sedentary behaviours, most of which involve sitting for long periods, have also been linked with an increased risk of all cause mortality (Katzmarzyk, Church, Craig and Bouchard, 2009). In a review of literature of sedentary behaviour and health indicators in school-aged children and youth, Tremblay et al. (2011) examined 232 studies and found that more than two hours of daily sedentary behaviour (which was measured in terms of time spent watching television) was linked with poor body composition and fitness levels, lower scores for self-esteem, and reduced academic achievement in those aged between 5 – 17 years. Strong et al. (2005) had previously recommended the reduction of sedentary behaviour to less than 2 hours per day in order to increase PA, thereby improving health. However, Tremblay et al. (2011) state that sedentary behaviour is a distinct behaviour and to encourage positive health, PA should be increased while at the same time decreasing time spent sedentary; especially among youth.

Koezuka et al. (2006) looked at the relationship between sedentary activities and physical inactivity among Canadian adolescents using self-report measures. A major finding from this research was that TV viewing was significantly related to inactivity among both boys and girls, while computer use was not implicated as a factor in replacing time spent in PA. Biddle, Gorely and Marshall (2009) conducted a study to test if TV viewing in teenagers was a broad marker of SB and found that it did not reflect additional time spent in other sedentary behaviours. The authors concluded that only using TV viewing as a measurement of SB may prove misleading because there are many other behaviours that can significantly contribute to sedentary time.

2.6.1 Relationship between Sedentary Behaviour and Physical Activity

According to Wong and Leatherdale (2009) SB and PA are not mutually exclusive activities; for example someone could be considered both highly active and highly sedentary. Indeed, there have been many studies on the relationship between PA and SB and most have found them to be uncorrelated (Melkevik, Torsheim, Iannotti and Wold, 2010). There have been claims that SB can affect participation in PA; often referred to as the displacement hypothesis, where one behaviour displaces another (Pearson, Braithwiate, Biddle, van Sluijs and Atkin, 2014). Melkevik et al. (2010) investigated if young people who exceeded the two hours of recommended screen time daily had reduced vigorous PA during their leisure time, or were less likely to meet the recommended 60 minutes of MVPA daily. The data used was part of the HBSC survey of 2005/2006. Their results rejected the displacement hypothesis in countries where young people spent more time in screen based sedentary activities. The authors suggested that inactive adolescents have more time to spend in screen-based SB rather than physical inactivity being the result of spending too much time in them. This was based on their findings of stronger negative associations between screen-based SB and PA in countries where PA levels were relatively high (Melkevik et al., 2010).

Iannotti et al. (2009) examined the relationship between PA and screen-based media SB (SBM) and psychological and social health among adolescents surveyed in the HBSC study during 2005-2006. They found that SBM was not significantly related to PA in three of the five regions surveyed. The authors concluded that PA and SBM are distinct, independent behaviours with their own specific health correlates. More recently, a cross sectional, self-report study on Greek-Cypriot children and adolescents PA and SB behaviours also found limited support for the displacement hypothesis (Loucaides, Jago and Theophanous, 2011). The study assessed the relationship between PA and eight different sedentary behaviours (including TV viewing, studying, using a computer, talking on the phone, listening to music, passive transport, video games and watching DVD/Videos). The only significant association found in the study between PA and SB was among the female cohort where girls who watched television for less than two hours per day were more likely to participate in PA.

A systematic review and meta-analysis carried out by Pearson et al. (2014) into the associations between SB and PA in children and adolescents found a significant, but small negative association between SB and PA with little support overall for the displacement hypothesis. The authors stated that their findings suggest that PA and SB should be considered separately.

2.6.2 Prevalence of Sedentary Behaviour

The American Academy of Paediatrics published a position paper on children, adolescents and the media in 2013 in which they stated that paediatricians should recommend to parents no more than 1-2 hours of screen time daily for children over the age of 2. HBSC participants across Europe were asked via self-report how many hours per day was spent watching television (including DVDs/videos) on weekdays and at weekends. Overall, 66% of 11-15 year olds watched 2 hours or more of TV on weekdays, with the Irish cohort slightly below this average at 62% (Currie et al., 2012). A significant increase in TV viewing from age 11 - 15 in just over half the countries, for both genders was also apparent. The Take Part Study (Woods et al., 2004) found that 70% of males and 60% females self-reported viewing time of ≥2 hours of TV daily. More recent data on this cohort has revealed that almost all (99%) Irish children spent more than 120 minutes per day in sedentary screen time (Woods et al., 2010). This is likely to be an underestimate of the time spent sedentary, given the recent increase in prevalence of hand held computer devices. For example results from the nine year old cohort of the longitudinal study *Growing Up in Ireland* (Williams et al., 2009) found that 86% of nine year olds reported having a computer; 91% used it to some degree - mostly for playing games. The same study found that two-thirds of children watched between 1-3 hours of TV daily while 10% reported watching three or more hours. Similarly, Lane, Harrison and Murphy (2014) found that 65.2 % and 64.1% of 9 year old boys and girls respectively reported 1-3 hours of screen time daily with approximately 9% watching 3 hours or more.

Time spent doing homework is also classified as SB. 14% boys and 25% girls in the Take Part study revealed that they spent ≥2 hours daily doing homework with more time spent on weekdays than weekends (2.7 v 2.4 hrs/day at weekend, $p<0.001$; Woods et al., 2004). The CSPPA study also found that girls self-reported spending more time doing homework than boys ($p<0.01$); the average primary school student spent about 20 minutes while the post-primary students spent just over an hour (67 minutes ± 56). Time spent doing homework increased as students progressed through school - all except for transition (fourth) year, where time spent on homework was less than in any other year (Woods et al., 2010).

According to a review by Salmon, Tremblay, Marshall and Hume (2011), school is likely to be a significant contributor to sedentary time. A recent study by Harrington, Dowd, Bourke and Donnelly (2011) used the ActivPAL accelerometers on 111 girls aged 15-18 to investigate the sedentary behaviour of adolescent girls in Ireland. The total percent of the day spent being sedentary was 78.4 ± 0.5% for weekdays and 78.5 ± 0.7% for weekends (p=.913.) Significantly more sedentary bouts occurred during a school day as opposed to a weekend day (53 vs. 49 bouts; p<0.001). Also, breaks in sedentary time (i.e. going form sitting/lying to standing/stepping) were less at the weekend than during weekdays (55 and 50 respectively, p <.001). When data were analysed over the school days, they found significantly longer bouts of >20 minutes of SB were accumulated during school hours.

In the US, participants in the NHANES study (n=6329), spent almost 55% of their objectively monitored time in sedentary behaviours (Matthews et al., 2008). This corresponded to 7.7 hours/day. One of the groups found to be most sedentary were older adolescents (16-19 years) who spent nearly 60% of their time in SB. Mitchell et al. (2012) conducted a large-scale study in the US to measure and depict longitudinal patterns of SB measured objectively from age 12-16. Participants (n=5436) wore accelerometers for 1 week at ages 12, 14 and 16 years. Results showed that at age 12, children spent more than 7 hours per day in SB. Similar to the cross sectional data of Matthews et al. (2008), time engaged in SB increased with age. Interestingly, this increase in SB was mostly at the expense of light PA, while MVPA remained relatively unchanged (Mitchell et al., 2012). In 2005, Treuth et al. also found significant increases in SB with age, again due mostly to a reduction in light-intensity PA.

A recent 5 year longitudinal study in Vietnam, described the changes in non-school SB among adolescents measured by both self-report and accelerometer (Trang et al., 2013). Time spent sedentary during the day was established by adding all sedentary activities which were categorised as: screen time (TV viewing, computer use for gaming/fun), educational time (studying, using a computer for studying), other leisure time (reading, chatting, talking on phone, hobbies such as music or painting) and passive commuting to school. Over the five-year period, sedentary time increased by 21% (p<0.001) from 498 minutes per day to

603 minutes/day. Age, sex, and socio-economic status (SES) were all related to screen time and total sedentary time.

Klitsie et al. (2013) also found that, in the UK, participation in various sedentary behaviours varied by sex and SES. SB was measured in 9-10 year old children (n=1513, 44.3% boys) using self report and accelerometry. Twelve leisure-time sedentary behaviours were measured by self-report. They found that boys SB time was made up of time spent watching TV/videos, playing indoors with toys, playing board games/cards and playing videogames. In contrast, girls mostly spent more time engaging in non-screen SB such as listening to music, reading and doing homework.

2.6.3 Correlates of Sedentary Behaviour

Based on the discussion above, it may be that the various biological, social and environmental reasons behind sedentary behaviour may be very different to those for physical activity (Katzmarzyk, 2010). Rhodes, Mark and Temmel (2012) in a systematic review on the correlates of SB in adults found most studies on SB focused on socio-demographic and behavioural correlates with a dearth of studies on cognitive, social or environmental categories. There are also relatively few studies which focus on the correlates of SB among youth (Van der Horst, 2007) and of those that have been done, the majority focus on time spent watching TV (Salmon et al., 2011). Because there are so few studies in this realm, it is difficult to be conclusive (Van der Horst et al., 2007). There have been some consistent correlates in relation to TV viewing; age ethnicity, socio-demographic status, having a TV in the bedroom, and parental viewing behaviour (Salmon et al., 2011). According to Lowry et al. (2013) adolescents that played on sports teams, had positive attitudes towards PA, and had parental support in relation to PA were also less likely to be sedentary.

Temmel and Rhodes (2013) found social influences, for example from peers and parents had significant correlations with SB in young people. Van Der Horst (2007) found gender to be a correlate of SB in adolescents. High screen time was found to be significantly associated with technology in the bedroom in both high and low active children in a recent study by Lane, Harrison and Murphy (2014). Similarly, young people with more access to electronic devices were significantly more likely to spend more time being sedentary than those with less access (Temmel and Rhodes, 2013).

Many studies have based SB correlates on those associated with PA (Salmon et al., 2011) and according to Van der Horst et al. (2007) variables such as self-efficacy, which have been consistently related to PA do not always share an inverse relationship with SB. In contrast, a recent cross-sectional study by King et al. (2010) looked at the correlates of objectively measured PA and SB in children in the UK using accelerometers. Results showed largely comparable correlates of habitual PA and SB. However, maternal age and parental modelling were significant correlates of SB only, and not PA. Active travel was found to be positively associated with total PA and MVPA and decreased SB.

It is clear that further research specifically examining the correlates of SB is needed. Salmon et al. (2011) recommend that more studies on SB - not just TV viewing - are needed. Temmel and Rhodes (2013) also suggest future research should focus on separate SB; i.e. computer use, TV time, homework time rather than analysing them as one behaviour.

2.7 Active Travel

Active travel (AT) is a term used to explain walking or cycling to get somewhere, while inactive travel refers to motorised means of travel, for example by car or bus (Woods et al., 2010). Active travel has been identified as a method of increasing daily levels of PA among children (Cooper et al., 2006) and adolescents (Van Dyck et al., 2010). Higher daily levels of PA and better cardio-respiratory fitness are associated with active travel to school (Davison, Werder and Lawson, 2008) as is favourable body composition and muscular fitness (Østergaard et al., 2013). Active travel to school has been shown to have a positive effect on cognitive performance (verbal and numeric ability and overall cognitive performance, $p<.05$) in adolescent girls compared to girls who did not actively travel to school, irrespective of confounders such as extra-curricular PA (Martinez-Gómez et al., 2011). Establishing and encouraging positive PA behaviour, such as AT, in childhood that can be continued into adulthood may lead to beneficial health effects throughout life (Cooper et al., 2006).

The numbers of students walking/cycling to school have sharply decreased over the past 30 years (Davison et al., 2008), while private car ownership has increased (Silva et al., 2011). For example, in the UK, the number of adults living in households with a car has increased from 59% in the mid-1970s to 80% in 2012 (Department for Transport, 2013). Similarly, in Ireland, 75% of adults who took part in the 2009 National Travel Survey (Central Statistics

Office, 2011), either owned or had regular access to a vehicle (not including company car pools).

2.7.1 Prevalence of Active Travel

2.7.1.1 Active Travel by Adults

Figures from the Irish Census 2011 revealed that 10.5% of all commuters walked to work (Central Statistics Office, 2012). The number of people cycling to work increased by 9.6% between the years 2006 to 2011 with 39,803 people cycling to work nationally. Previously, the National Travel Survey 2009, compiled and published by the Central Statistics Office (CSO; 2011) surveyed 7,221 adults over the age of 18 in relation to their travel behaviour. Walking was found to be the second most popular transport mode, after private car use, with 16% of all journeys made by walkers. Cycling accounted for just 1% of travel. Local area statistics from the Central Statistics Office (2012) show that for all people over the age of 15 that travel actively to school, work or college in Carlow; 15% walk and almost 1% cycle. Meanwhile, in the UK, the National Travel Survey: 2012 undertaken by the Department for Transport (2013) collected data from 8,200 households (incorporating over 19,000 people) including adults, adolescents and children. Overall, 22% of trips were taken on foot while biking accounted for 2% of trips. Cycling was more common among men (23 cycle trips per year compared with 9 trips by women).

2.7.1.2 Active Travel by Children and Adolescents

The most recent census figures in Ireland have shown that six out of ten children (61%) are driven to primary school. Twenty five percent of primary school students walked to school; compared to 50% back in 1981 (CSO, 2012). Similarly, Murtagh and Murphy (2011), in a study on primary school children aged 9-11years in Ireland, found that 62.1% travelled by car, 36.4% walked to school, one child travelled by bus and one child cycled. The *Growing Up in Ireland* Study (Williams et al., 2009) collected data on a representative sample of nine year olds in Ireland and found that 60% travelled by car, 14% by bus or other public transport, while 25% walked to school and 1% cycled.

The car is also the main travel mode (41%) for second level students in Ireland according to CSO figures (2012). Among this cohort, 24% walk to school while just 2% cycle; a figure that has dropped a massive 87% since 1986 (CSO, 2012). These figures are less than those found by Woods et al., (2010) who determined that 40% of post-primary school students walked to school; while 3% cycled. There was a significant difference between boys and girls, with girls less likely to travel actively than boys (38% vs 43%, p<0.01).

The Travel Survey for Northern Ireland (2011-2013), commissioned by the Department for Regional Development (2014) found that between the years 2011-2013, the bus was the most common method of travel to school (52%) for adolescents aged 12-18. This was followed by car (32%), and walking and cycling combined contributed to 15% of all journeys to or from school. In contrast, according to the Irish HBSC survey 26.5% of school children aged 10-17 years reported that they actively travelled to school. Boys were found to be more likely to actively travel to school (28.1% versus 24.7% of girls; Clarke et al, 2013). When compared to ten other countries in Europe and North America also involved in the HBSC study, Ireland were ranked 9th for each of the 11, 13 and 15-year old age groups. *Table 1* below summarises some of the relevant studies containing AT prevalence data for Europe.

Table 1

A summary of studies relevant to AT prevalence in Europe

Author (Year) and Setting	**Methods and Population**	**% walking and cycling**
Woods et al. (2010) Ireland	Cross-sectional sample, nationwide One-stage cluster method Multiple methods: self-report surveys, objective measures & qualitative interviews	40% 12-18 years olds walked to school 3% cycle
Central Statistics Office (2012) Ireland	Self-report questionnaires from all households nationwide	24% second level students walked to school 2% second level students cycle
Department for Regional Development (2014) Northern Ireland	Representative sample Computer interview and self-report	15% of 12-18 year olds walk/cycle to school
Clarke et al. (2013)	Representative sample	26.5% of 10-17 year olds

HBSC Ireland	Self-report	walk/cycle to school
Department for Transport (2013) UK	Representative sample Personal interviews and self-report survey	38% journeys to school on foot 2% by bicycle
Van Dyck et al. (2010) Belgium	Random selection Self-report	58.4% of 17-18 year olds travelled actively to school 88.7% cycled; 11.3% walked
Østergaard et al. (2013) Norway	Cluster sampling Information on transport to school by self-report	42% adolescents walked to school 23.3% cycled
Van Sluijs et al. (2009) UK	Cross-sectional results with data from Avon Longitudinal Study of Parents and Chidren Prospective birth Cohort Study	41.5% of 11-12 year olds walked to school; 2% cycled
Roth, Millet and Mindell (2012 UK	Cross-sectional Nationally representative sample using two-stage, stratified, random probability sample Self-report by parents or child	64% of children ages 5-15 walked to school; 3% cycled
Cooper et al. (2006) Denmark	Two-stage Cluster Sample Data on mode of travel to school collected via self-report	65.6% adolescents cycled to school; 20.8% walked
Børrestad, Andersen and Bere (2011) Norway	Random sampling Self-report	36% of 10-12 year olds cycled to school; 28% walked

2.7.2 Active Travel Policy

The importance of AT as a means of contributing to PA and health is becoming increasingly more visible at policy level. Many countries have compiled policies for sustainable and active travel. In Ireland, active travel policy is coordinated by the Department of Transport, whose motivation is more about easing traffic congestion, reducing emissions and benefitting the economy. A new physical activity plan is currently being developed as part of the new public health policy for Ireland, Healthy Ireland, and this is jointly chaired by the Departments of Health and Transport. The Smarter Travel policy is an important component of this policy. *SmarterTravel, A Sustainable Transport Future*, is the transport policy for the period 2009-2020 (Department of Transport, 2009a) which outlines a plan for sustainable travel in Ireland. The Smarter Travel Programme includes a number of initiatives including the National Cycle Policy, Smarter Travel Towns and Smarter Travel at work programmes. Irelands first National Cycle Policy Framework was published under the Smarter Travel Programme with a vision to create cycle friendly cities, towns, villages and rural areas throughout Ireland (Department of Transport, 2009b). For schools, there is a Green-Schools programme which is coordinated by the Environmental Education Unit of An Taisce in partnership with Local Authorities. One of the themes of the Green-School programme is Travel, which is funded by the Department of Transport, Tourism and Sport. The aim is to increase the number of students who walk and cycle to school and to ease congestion through park ‘n’ strides, car pooling and public transport use. To monitor the programme, An Taisce conducts up to four surveys in the schools in each academic year. The student surveys are mostly conducted by a Green-Schools Travel staff member through use of a questionnaire in which students answer questions by raising their hands. The Annual Report 2012 revealed that over the period September 2010 to June 2012, there was an overall 15.6% decrease in the numbers of students travelling to school by car. This was accompanied by a 6.2% increase in students walking to school and 2% increase in cycling to school by students (An Taisce, 2012). While these surveys are done subjectively, and therefore results may be inflated, it is an indication that more students are beginning to actively commute to school. The programme also shows the commitment by schools to try and increase the numbers of students who travel to school by foot or bicycle.

Established in 2009, the Active Schools Flag (ASF) is a national self-evaluation programme which focuses on the provision of PA through PE, co-curricular PA and sport in primary schools. One of the goals of the programme is the promotion of AT to school. An evaluation of the programme carried out by Ní Chróinín, Murtagh and Bowles (2012) found that overall, the ASF process had a positive impact on the participating schools in terms of a more structured and inclusive approach to the promotion of PA. The Health Service Executive in

Ireland also have a publication titled 'Schools for Health in Ireland: Framework for Developing a Health Promoting School, Post-Primary' which outlines to schools how they can assess their current health needs and address these through health promotion initiatives. The Childhood Development Initiative also run a Healthy Schools Programme which is based on the WHO model for a health-promoting school (Comiskey et al., 2012). One of the initiatives within this programme is the promotion of walking to school and a walk on Wednesday (WOW) campaign. In an impact evaluation of the programme over 3 years by Comiskey et al. (2012), no significant differences were found between the intervention and comparison schools. However, according to the authors, it can take time for schools to implement and accept the principles of a 'healthy school' and therefore, expectations of changes in the shorter term should be low.

2.7.3 Independent Mobility

Levels of independent mobility have decreased since the 1970's; for example, in the UK, 86% of parents in 1971 would have allowed their children to travel home from school alone compared to just 25% in 2010 (Shaw et al., 2013). During adolescence, independent mobility increases as children are given more autonomy and permission to cycle independently (Ducheyne et al., 2012). Increasing cycling behaviour may help to counteract the decline in PA and sports participation that occurs in adolescence (Ducheyne et al., 2012). Schoeppe et al. (2013) in a systematic review on the association between independent mobility and AT with PA, SB and weight status in children, found that there was a positive relationship between independent mobility and PA. Independent mobility has also been associated with increased sociability and better mental well being (Shaw et al., 2013). Therefore, there seems to be a positive health benefit to allowing children the freedom to actively travel or play outside without the supervision of an adult. A study involving 850 parents by Ducheyne et al. (2012) assessed the correlates of the cycling behaviour of their children aged 10 - 12 years and found that children who were given permission to cycle alone within a certain distance of the home were more likely to always cycle to school and less likely to never cycle to school.

2.7.4 How successful are interventions to promote AT?

With the decrease in levels of children and adolescents walking and cycling for transport, interventions to promote AT are needed. According to Chillón, Evenson, Vaughn and Ward

(2011a), studies on AT to school is a quite new area of research; therefore intervention studies are also not yet fully developed. School-based AT interventions are varied and examples include; use of a travel coordinator; local authority activities to promote safe neighbourhoods; distribution of safety and promotional literature to encourage alternative modes of transport to school; classroom based modules; and the organisation of walking buses (Hoskings et al., 2010). A systematic review on interventions promoting AT to school was carried out by Chillón et al. (2011a). Fourteen interventions to increase AT to school were identified, primarily using primary school children. The interventions were diverse, with a range of sample sizes and aims. There was an increase in the numbers of those who actively travelled to school in almost all the intervention studies; however, this ranged from 3% to 64%. Two studies reported no significant increases in AT to school while another two studies found improvements in other outcomes such as an increase in PA and longer distances walked to school (Chillón et al., 2011a).

The Sustrans Bike It project in Wales, which aims to promote and encourage cycling in schools across Wales, saw an increase from 3% - 11% of students cycling to school three or more times per week in the 2012/2013 academic year; this was an increase of over 300% (Sustrans Cymru, 2013). Wen et al. (2008) conducted a cluster randomised controlled trial in Australia that consisted of a multi component intervention to increase AT to school over a two-year time period. Classroom activities, parent newsletters, school travel access guiles and improved environment in conjunction with the local councils were all part of the programme. The evaluation of the programme yielded varied results; parents reported an increase in walking by their children however the children themselves did not report these findings. There was a lot of variation inter-schools with both increases and decreases in walking which suggested that factors at local level influence how children travel to school.

Ogilvie et al. (2007), in a systematic review on interventions to promote walking, found that overall, interventions to promote walking could help to increase the PA levels of those people who are considered the most sedentary. Findings showed that people responded differently to approaches, and therefore various types of methods should be offered; for example the use of pedometers, internet-delivered interventions and walking groups. The authors did find that interventions that were specific to the needs of the person, targeted at those who were most sedentary and implemented at an individual, household or group level were the most successful. More research is needed into interventions that take place at institution level - such as schools and workplaces (Ogilvie et al., 2007).

One of the limitations in intervention study design highlighted by Chillón et al. (2011a) was the lack of interventions that accounted for distance; considering it is has been shown to be one of the strongest predictors of AT to school.

2.7.5 Contribution of Active Travel to daily Physical Activity

Active travel to school has been recognised as an important source of PA for youth (Lubans, Boreham, Kelly and Foster, 2011). In Ireland, Murtagh and Murphy (2011) investigated mode of transport with objectively measured PA levels in primary school children aged 9-11 years. Using pedometers to measure step counts, the authors found that children who walked to school had approximately 21% higher total PA daily than those who commuted passively.

According to Cooper et al. (2006), total PA might also be affected by the distance travelled to school; in Denmark, those who live within 1km of school will usually walk to school while those living further than 1km will often cycle. The study found similar times for travel to school for both walkers and cyclists; therefore implying that the cyclists travelled further and so it is possible that their overall PA was more than that recorded by accelerometer (Cooper et al. 2006). *Table 2* presents a summary of studies that examine the relationship between AT to school and PA.

Table 2

A summary of studies examining the association between active travel to school and physical activity in children and youth

Author (Year) and Setting	Methods	Population	Results
Carver et al. (2011) Melbourne, Australia	Longitudinal study on association between AT and children's PA over time MVPA assessed using accelerometers AT measured with surveys	T1 Baseline: Cohort 1 aged 5-6, n=295 Cohort 2 aged 10-12, n=919 T2 Follow up at 3 yrs Cohort 1 aged 8-9, n=191 Cohort 2 aged 13-15, n=416 T3 Follow up at 5 yrs Cohort 1 aged 10-11, n=177 Cohort 2 aged 15-17, n=326	AT was positively linked with MVPA for boys at an earlier age, but both boys and girls in later adolescence. The authors suggested that AT could be an important contributor to regular PA for adolescent girls, as this is a time when overall PA levels begin to decline among girls in particular.
Smith et al. (2012) UK	Population-based longitudinal study on change of travel mode to school and its possible associated effect on PA levels	812 children Age 9-10	Children who changed from passive to AT increased their MVPA daily by an average of 9 minutes for boys and 6 minutes for girls; which represented 12% and 13% of their total daily MVPA respectively at follow-up.

	Data collected via questionnaire (AT data) and accelerometer (PA data)		Children who chose to travel by motorised means were found to have a decrease in MVPA daily over the same time span.
Alexander et al. (2005) Scotland	Cross sectional study on the impact of walking to school on MVPA PA measured by accelerometry AT information gathered via questionnaire	103 adolescents Mean (SD) age: 13.8 (0.27)	Walking to school positively associated with higher MVPA throughout the day when compared to those who travelled passively
Van Sluijs et al. (2009) UK	Cross-sectional study to assess the relationship between AT to school and objectively measured PA.	4688 children Mean age (SD): 11.8 (0.2)	Walking to school associated with almost 6 minutes > MVPA on weekdays for children living between 0.5-1 mile from school and 9.7 minutes for those living 1-5 miles away. The increased activity levels were solely found on weekdays with no differences found outside of travel times.
Chillón et al. (2011b) 10 European Cities	Cross sectional study examining commuting patterns in adolescents and its association with PA Active Commuting behaviour gathered using IPAQ-A PA behaviour measured by	3112 adolescents Age range: 12.5 - 17.49 years	AT time associated with higher PA daily; boys and girls PA through AT had a bigger effect on vigorous PA in boys than girls.

	accelerometer		
Owen et al. (2012) UK	Cross-sectional study on travel to school and PA in children PA measured with accelerometers AT data gathered using questionnaires	2035 children Mean (SD) age: 9.9 (0.4)	AT to school associated with higher levels of PA both during the week (7 minutes > MVPA) and also at weekends (5 minutes > MVPA). Children who used public transport had equal or higher PA levels than those who walked/cycled. The rationale given was that those children had to walk to and from public transport.
Roth et al. (2012) England	Cross-sectional study on contribution of AT to overall PA in children PA and AT data collected by questionnaire for total study sample Sub-sample also wore accelerometer for PA data collection	4,468 children Age range: 5-15 years	Data from questionnaires found that cycling was significantly associated with meeting the PA guidelines ($p<0.001$) Accelerometer data similar to main results; children who AT to school more likely to be in high/middle tertile of PA compared to those who travel by motorised means.

2.7.6 Does Active Travel displace Physical Activity?

There is a hypothesis that more PA at one time is compensated for by reduced PA at another time (Frémeaux et al., 2011). This is known as the 'activitystat' hypothesis (Frémeaux et al., 2011), also called activity compensation (Goodman, Mackett and Paskins, 2011). There is no concrete evidence for activity compensation (Goodman, Mackett and Paskins, 2011) and to date most studies have been observational in nature (Gomersall et al., 2012). A recent review on the activity stat hypothesis found that of the 28 studies included, 46% did not provide evidence of PA displacement/compensation (Gomersall et al., 2012).

Garrard (2011) in a review of active travel literature, stated that it is not just children who are already active that participate in AT and AT does not necessarily displace other types of PA. Also, increasing AT in children will possibly result in an overall increase in PA levels and the number of children reaching the minimum guidelines of PA. Roth et al. (2012) found that children who walked or cycled to school had similar or higher levels of other types of PA as those who travelled to school by motorised means. This suggests that AT does not displace other forms of PA.

Goodman, Mackett and Paskins, (2011) conducted a study to examine activity compensation and synergy in 8-13 year olds (n=345) in the UK. None of the PA behaviours examined (including PE, school break time, school AT and school non-AT and structured sports) showed evidence of activity compensation and all were independent predictors of higher total MVPA. Interestingly, non AT was reported to have activity synergy with play and visiting friends; each 1% of extra time spent in non active travel to school was associated with between 0.36% - 0.38% increase in the amount of time spent in MVPA throughout the rest of the day.

Some studies have shown that participants who take part in AT are more likely to meet recommended levels of PA, which indicated that AT does not displace other forms of PA (Garrard, 2011). For example Owen et al. (2012) found higher levels of MVPA at weekends in children who travelled actively compared to those who did not.

2.7.7 Active Travel and Health Related Fitness

A recent study by Østergaard et al. (2013) found that AT, in particular cycling, has a positive association with body composition, cardio-respiratory fitness (CRF) and muscular fitness when compared to passive commuting in children and adolescents. Cooper et al. (2006) also found that cycling to school was related to higher CRF compared to passive transports in young people aged 9 and 15 in Denmark and results were similar for both children and adolescents and boys and girls. Both studies revealed that walking to school was not associated with higher CRF. Cooper et al. (2006) suggested that the higher CRF in cyclists may be due to higher intensity of cycling compared to walking or a greater commuter distance - or even a combination of the two. Also CRF was measured using cycle ergometer test; therefore it is possible that those familiar with cycling performed better on the test. However the authors did say that cycling is very popular in Denmark and so it is unlikely that those who walked or travelled to school by motorised means were completely unfamiliar with cycling.

In their systematic review, Lubans et al. (2011), found that after removal of poor-quality studies in relation to AT and weight/body composition, 55% of studies reported AT to be associated with lower body fat. Additionally, AT was associated with higher cardio-respiratory fitness in the five relevant studies reviewed, which included one longitudinal study. Østergaard et al. (2013) also found higher isometric muscle endurance in back extensors in both walkers and cyclists compared to non active travellers; this might potentially be relevant in the prevention of back pain.

Some authors have raised concerns about the limitations in studies examining the associations between AT and both PA levels and health related fitness. For example, Lubans et al. (2011) conducted a systematic review of the literature pertaining to the relationship between AT and health-related fitness and found similar limitations in relation to the overall quality of the studies, especially regarding the definition and measurement of AT to school. They found a range of definitions for categorising participants as active travellers and also various classifications of frequency, duration and type of activity that counted as AT. These matters were also raised by Saunders et al. (2013a) who also reported their concerns about comparing AT intensity between studies, when things like traffic congestion, climate and terrain can affect the intensity of a journey of similar time and length in different places.

Another limitation mentioned by Lubans et al. (2011) was that the majority of study populations were homogenised into two groups, i.e. AT versus non-AT groups, and therefore the associations between sub-groups such as gender and age were not examined. A number of studies have also expressed the need for more longitudinal and intervention studies in this area (Lubans et al. 2011; Roth et al., 2012). Because of the cross-sectional nature of many studies into AT and levels of PA, causality cannot be determined (Smith et al., 2012) i.e. are those people who are active more likely to AT to school and respond to interventions promoting AT or does the encouragement of AT then affect overall PA levels (Roth et al., 2012).

2.8 Measurement of Physical Activity

An important component of health promotion research is the measurement and monitoring of behaviours and their corresponding attributes (Bauman, Phongsavan, Schoeppe and Owen, 2006). The measurement of PA behaviour can pose many challenges, due to the frequency at which it occurs over 24 hours, the various domains in which it can occur such as during work, in the home, and during leisure time, and also because it can be classified in numerous ways (e.g. frequency, intensity, type, duration etc; Welk, 2002).

The validity and reliability of the method used to measure PA is of utmost importance (Adamo et al., 2009; Prince et al., 2008, Biddle et al., 2011). According to Bauman et al. (2006), valid and reliable methods of the measurement of health behaviours are essential to health promotion research and evaluation. In terms of measuring habitual PA, validated measurement techniques are required to establish the relationship between PA and health (Westerterp, 2009). Reliability in PA measurement refers to repeatability; i.e. the ability to repeat a measurement and achieve similar scores (Bauman et al., 2006) It must be established before a measurement can be classed as valid (Morrow, 2002). Validity refers to the truthfulness of the measurement and is divided into three types; content, criterion and construct (Morrow, 2002). Measurements used in PA research studies are often validated against some criterion or ‘gold standard’ (Bauman et al., 2006). One type of criterion validity is concurrent validity, where an instrument is correlated with some criterion that is carried out at the same time (i.e. concurrently; Thomas and Nelson, 2001).

While there are many ways of measuring PA among children and adolescents, the method chosen may not necessarily accurately assess their levels of actual PA (Bates, 2006) and each method will have its own strengths and weaknesses (Loprinzi and Cardinal, 2011). Ideally, measurement should take place during normal daily life and be over a period of time that accurately reflects regular activity levels. It is also important to assess PA patterns - frequency, duration and intensity - as well as PA energy expenditure (Plasqui and Westerterp, 2007).

Measurement of PA can be divided into subjective and objective methods. Subjective methods include questionnaires, surveys, and diaries (Yang and Hsu, 2010, Biddle et al., 2011) while objective methods involve measurement of physiological parameters (e.g. heart rate, body temperature) and motion sensors (e.g. pedometers and accelerometers) with the information gathered used to estimate PA outcomes (Corder et al., 2008; Plasqui and Westerterp, 2007). Prince et al. (2008), in a review of studies on the levels of agreement between objective and subjective measures of PA, found that the actual method of measurement can significantly affect the levels of PA. According to Janz (2006) a combination of both objective and subjective techniques is the best way to measure PA.

2.8.1 Subjective Methods

As previously mentioned, subjective methods of PA assessment include questionnaires, interviews, activity diaries and direct observation (Corder et al., 2008). Diaries, surveys and questionnaires are inexpensive subjective methods of PA measurement (Yang and Hsu, 2010). Self-administered questionnaires are the most widely used method of PA assessment because they are low cost and simpler to use in studies with large sample sizes (Slootmaker et al., 2009).

2.8.1.1 Direct Observation

Direct observation is a method whereby a trained observer objectively records and classifies subjects' free-living PA over a period of time, usually within natural settings i.e. during school or at home (Loprinzi and Cardinal, 2011). It has been shown to be both valid and reliable for measurement of PA in children (Rachele, McPhail, Washington and Cuddihy, 2012). McKenzie (2002) reviewed 9 different protocols of direct observation compared with objective measures such as accelerometry, heart rate monitoring and indirect calorimetry and found good indications of concurrent validity in 8 of the 9 studies. There was also substantial inter-observer reliability with kappa values >0.90. One of the major disadvantages of direct observation is that it is labour intensive and therefore expensive, and so it may not be suitable for studies involving large sample sizes or for long periods of observation (Rachele et al., 2012; Armstrong and Welsman, 2006). Direct observation can also cause subject reactivity (Armstrong and Welsman, 2006). However, it is a useful approach for assessing PA within a controlled environment and also as a validation criterion (Corder et al., 2008).

2.8.1.2 Activity Diaries

While activity diaries may be too complicated for use with children, they have been used effectively with adolescents (Sirard & Pate, 2001). Diaries are a convenient and inexpensive method of measuring PA compared to criterion methods such as doubly labelled water and accelerometry (Koebnick et al., 2005). However, according to Sternfeld et al. (2012), traditional pen and paper based diaries are prone to measurement error and require high compliance from participants. Their study evaluated a mobile phone based activity diary and found that it provided valid measures of PA and was also convenient for participants, therefore promoting high compliance in its use. With the on-going development of technology, the use of mobile phone PA diaries in research may increase over the next few years (Sternfeld et al., 2012).

2.8.1.3 Self – Report

Self-report instruments include questionnaires, journals and surveys and are a straightforward method of gleaning information on PA in children and youth (Bates, 2006). While questionnaires are disposed to error depending on the type of activity being measured and the time frame involved, this is often offset with large sample sizes and therefore continues to be one of the most popular methods of PA measurement in epidemiology (Janz, 2006). According to Bauman et al. (2006), self-report measures are both convenient and inexpensive and, if the right instrument is used, they can gather useful information.

As indicated above, while self-reporting is a valuable method of gathering information regarding population PA levels, there can often be over- or under- estimation of PA energy expenditure and inactivity levels (Prince et al., 2008). According to Biddle et al. (2011) there are also issues of recall with self report, especially with young people. Adamo et al. (2009) in a review of the literature of the extent of agreement between direct and indirect measures of PA among children and adolescents found that 72% of the indirect measures (e.g. questionnaires) overestimated measures taken directly (e.g. by accelerometer). They found that reliability may be affected when using self-report methods of assessment with adolescents due to difficulty in recalling information while the validity can be compromised by answering in a way they feel is expected of them. Similarly, Prince et al. (2008) examined the literature in relation to the level of agreement between direct and indirect measures of PA assessment among adults, and found no clear trends in terms of over/under estimation of PA. However, the strength of the trends depended on the direct method used and the sex of the sample population. For example, self-reported PA was overestimated by overweight/obese population samples (Prince et al., 2008). Slootmaker et al. (2009) measured PA (MPA and VPA) in adolescents (n=236) and adults (n=301) using both questionnaire and accelerometer and found good agreement in adults; however, there were large differences in the adolescent group.

There are many self-report instruments available for use with children and adolescents. Chinapaw et al. (2010) in a systematic review of measurement properties of PA questionnaires for youth concluded that no questionnaires available at the time had both acceptable validity and reliability and recommended that further high-quality research is required to investigate possible PA questionnaires for adolescents. However, according to Rachele et al. (2012), accuracy versus resources available will always be a dilemma for researchers measuring PA among youth.

2.8.1.3.1 International Physical Activity Questionnaire (IPAQ)

The IPAQ is a tool used to measure health-enhancing PA and it was developed to enable comparability of PA internationally. The validity and reliability of the instrument was originally tested in 2000 by Craig et al. (2003) who collected data in 14 centres across 12 countries. In the validity study, participants wore an accelerometer to objectively measure activity levels. Spearman correlation coefficients on test-retest reliability of the long form of the IPAQ averaged 0.8 which suggested very good repeatability. The criterion validity of the IPAQ against accelerometers showed fair to moderate agreement for a sample of 744 adults. Concurrent validity between the long and short forms of IPAQ showed reasonable agreement. The authors concluded that the IPAQ was at least as good as other established methods of self report but that care should be taken when comparing long and short forms as the longer forms tended to have higher estimates of PA than the short form.

The IPAQ was originally developed for adults, but was adapted for the assessment of PA in adolescents (IPAQ-A) by changing the 'work' domain to 'school', adding questions about PE class and break times. Also, only one question was asked in relation to the housework/gardening domain (as opposed to three in the adult version) and finally, the order of intensities was changed as advised by Barnett et al. (2007) who found that the level and duration of reported PA is affected by the order in which options are presented. The concurrent validity of the IPAQ-A was investigated by Hagstromer et al. (2008) using 248 adolescents from nine countries across Europe. The study involved comparing data from an accelerometer with data from the IPAQ-A. Results showed significant correlations for the older adolescent group (15-17 years old) for walking, moderate, vigorous and total PA (r's=0.17-0.30, $p<0.05$) while none were found for the younger 12-14 year old age group for any of the variables. They concluded that the IPAQ-A had acceptable validity for the older adolescents, but that objective data collection may be more appropriate for the younger group. Ottevaere et al. (2011) suggested that comprehension of the questions between younger and older adolescents may be a possible reason for the large differences found between data collection methods.

As part of the HELENA (Healthy Lifestyles in Europe by Nutrition in Adolescence) study, Ottevaere et al. (2011), assessed PA using the IPAQ-A and compared data to accelerometers and VO_2 max (as estimated from the 20-m shuttle run test). The study was carried out on 2018 adolescents (46% male) from ten European cities. The authors found a poor-to-fair relationship between both methods of PA measurement. Correlations were highest for vigorous intensity activity, which has also been found in previous studies in adolescents (Lachat et al., 2008) and adults (Hagstromer et al., 2006). Both the questionnaire and accelerometers were moderately correlated with estimated VO_2 max and therefore, can assist in identifying those adolescents who are the most physically active in a large population.

2.8.2 Objective Methods

According to Biddle et al. (2011), objective methods of PA measurement are used more frequently now than in the past, because issues of cost and complexity have been overcome somewhat. Objective, or direct, measures of PA include doubly labelled water (DLW), indirect/direct calorimetry, physiological (e.g. heart rate monitoring, respiratory rate) and motion sensors, including pedometers and accelerometers are often used to increase accuracy of measurement and validate self-report or other subjective measures. Advantages of using objective measures include accuracy and the removal of recall and response bias. However, they can prove to be time-consuming, expensive and invasive thereby making them unsuitable for use in large-scale studies (Adamo et al., 2009).

2.8.2.1 Doubly Labelled Water

The doubly labelled water (DLW) technique is deemed the gold standard for energy expenditure (EE) measurement (Armstrong and Welsman, 2006) because it can accurately measure EE in daily living over long periods of time (Plasqui and Westerterp, 2007). The DLW method involves the participant drinking stable, non-radioactive isotopes which tag oxygen and hydrogen. Elimination of these isotopes is then measured (by urine, blood or saliva sample) and used to estimate carbon dioxide production which is then converted to energy expenditure. While this is considered an accurate measurement of EE, it does not capture PA and is therefore expected to overestimate PA levels (Prince et al., 2008). DLW is an expensive method of PA measurement and therefore is mostly used in studies using small populations (Armstrong and Welsman, 2006; Plasqui and Westerterp, 2007).

2.8.2.2 Heart Rate Monitoring

Heart Rate (HR) monitoring is a popular method of assessing PA because of the linear relationship of the HR response to steady-state exercise (Trost, 2001). The negative aspect of HRM is that heart rate is influenced by factors such as age, body size, emotional stress and cardiovascular fitness. There is also no agreement in terms of the HR indices which should be used to quantify PA in youth (Adamo et al., 2009).

2.8.2.3 Pedometers

Pedometers are small unobtrusive devices which measure ambulatory activity by estimating PA in relation to the number of steps taken. They have in-built horizontal spring-suspended level arms which move up and down with vertical accelerations at the hip (Tudor-Locke and Lutes, 2009). They can provide information such as number of steps taken, the distance covered, time spent in PA and some can also estimate energy expenditure (Lubans et al., 2009). However, one of the major drawbacks of pedometers is they do not have the functionality to measure frequency, duration or intensity and therefore are limited in terms of measuring activities of daily living (Plasqui and Westerterp, 2007). Waist-mounted pedometers are incapable of measuring PA during cycling or increased EE due to carrying objects or going uphill (Armstrong and Welsman, 2006). A recently published study by Scott et al. (2014) found that both reactivity and tampering occurred when using pedometers with adolescents, suggesting that the protocol used for pedometer monitoring affects PA behaviour and compliance among this age group.

2.9 Measurement of Physical Activity using Accelerometers

Accelerometers are small unobtrusive measurement devices, which provide an objective assessment of PA by recording bouts of PA. They fall under the category of motion sensors and are possibly the oldest tools available for measuring PA (Plasqui and Westerterp, 2007). According to Troiano (2005), significant advances have been made in the field of accelerometry since the early 1980's. During the time span 1981 - 1996, approximately 10 studies per year could be found on accelerometer use; with a dramatic increase to almost 90 in 2004. Reviews of accelerometry have shown their use to be precise in terms of measurement of PA during all intensity levels – from sedentary to vigorous (De Vries et al., 2006; Biddle, Pearson, Ross and Braithwaite, 2010).

Over time, accelerometers have evolved from mechanical pedometers to electronic uniaxial and triaxial measuring devices (Plasqui and Westerterp, 2007). Accelerometers contain acceleration sensors, which emit a variable output voltage signal proportional to the acceleration detected. This signal is then filtered and amplified and converted to a digital series of numbers known as raw counts which are then converted into user-defined epochs (Chen and Bassett, 2005). Accelerometers can be uniaxial, measuring acceleration in one direction, usually vertical, while triaxial accelerometers measure in three planes; aneteroposterior, mediolateral and vertical (Plasqui and Westerterp, 2007). Triaxial accelerometers measure acceleration in three planes by three different internal accelerometers, which are at 90 degrees from each other and can provide a better measurement of overall body movements (Berlin, Storti and Brach, 2006). As previously mentioned, data from accelerometers are expressed as counts which are dimensionless units whose values vary depending on the brand of monitor used. Accelerometers have an internal clock which time stamps the counts thereby allowing activity to be broken down minute by minute. This also makes it possible to ascertain a reliable measurement of time spent in different activity intensities (Berlin et al., 2006).

The benefits of using accelerometry is that information on total PA, frequency, intensity and duration can be measured (Plasqui and Westerterp, 2007). They also offer a higher degree of accuracy over self-report measurement (Strath, Pfeiffer and Whitt-Glover, 2012). PA involving most lower-extremity or trunk acceleration e.g. running, walking, stair climbing can be measured by accelerometers. However, there are also a number of challenges associated with accelerometer use. Activities involving upper extremities are difficult to measure because accelerometers are usually worn on the leg/waist as are seated exercises such as cycling (Berlin et al., 2006). Another challenge of using PA monitors, including accelerometers, is the lack of standardized quality control procedures to help identify incorrect data that might occur for a number of different reasons; for example monitor malfunctions, participant tampering and human error (Matthews, Hagstromer, Pober and Bowles, 2012). In addition, the frequent updating and changes of hardware and firmware make it harder to compare output, even among different models from the same manufacturer (Welk, McClain and Ainsworth, 2012). Ward et al. (2005) summarise the challenges of accelerometer use as; a lack of understanding in relation to exactly how monitors work, choosing the correct monitoring device, and how to process, analyse and interpret data produced.

2.9.1 The Use of Accelerometry in Research studies

The use of accelerometers has grown widely in research studies, among a variety of populations, to assess PA levels. In the United States, accelerometers have been used by researchers in the National Health and Nutritional Examination Survey (NHANES) since 2004 to assess patterns of PA among adults (Metzger et al., 2008) and children/adolescents (Troiano et al., 2008). Accelerometers are not only used for assessing PA levels, but also as a criterion method for validating other methods of PA assessment (Ward et al., 2005) and in intervention studies (Napolitano et al., 2010).

Accelerometers have become one of the most popular measurement tools for assessing PA amongst children (Loprinzi and Cardinal, 2011). They have been used to compare PA across European countries among children and adolescents (Riddoch et al., 2004; Yildrim et al., 2011). They have also been used in field based research with children and adolescents with intellectual disabilities (McGarty, Penpraze and Melville, 2014). In Ireland, the CSPPA study used accelerometers to objectively measure PA and validate the self-report instrument amongst children and adolescents (Woods et al., 2010). Harrington et al. (2011) also used accelerometers to measure sedentary behaviour in adolescent girls in Ireland.

2.9.2 ActivPAL Accelerometer

The ActivPAL is a uniaxial accelerometer which has the ability to detect different postures (i.e. sitting/lying and standing) and periods of walking (Welk et al., 2012). It also shows the duration of these events, number of steps per day and the cadence of walking periods (Grant et al., 2006).

The ActivPAL weighs 15g and is capable of recording over seven days continuously. Data is recorded in 15-second bouts (epochs) using algorithms, which can then be downloaded and converted to an Excel document and into SPSS for further analysis (Taraldsen et al., 2011). It is worn on the anterior right thigh and attached directly to the skin using PAL stickies which are hydrogel adhesive pads. It must be taken off when showering/bathing, doing water sports, or any other activities in which it maybe become wet.

2.9.3 Validation of Monitors

The aim of validation and calibration studies is to determine the association between actual PA carried out and the signals created by objective monitors (Strath et al., 2012). Bassett, Rowlands and Trost (2012) point out the importance of noting that validation is not of the actual instrument, but the purpose for which it is being used. Therefore, a device might be valid for assessing one outcome variable such as MVPA, but not energy expenditure. While indirect calorimetry has been the main method used as a criterion measure for validating accelerometers, DLW and direct observation have been used more recently, especially in younger children (Strath et al., 2012).

Validation studies are performed using a variety of methods. For example, Dowd et al. (2012) used two accelerometers and a VO2 measuring device while performing a number of activities including sitting, standing, stepping. MET (metabolic equivalent of a task) values were compared to ActivPAL counts. Count functions between both accelerometers were also compared. Aminian and Hinckson (2012) examined the validity of the ActivPAL in children in a laboratory setting. Measurements of lying/sitting, standing, walking time, transition and step counts were measured by video observation, two pedometers and compared to the ActivPAL.

Plasqui and Westerterp (2007) conducted a review of 28 studies validating accelerometers with DLW. Eight different accelerometers were identified. Poor results were found in many of the studies; with large standard errors and non-existent limits of agreement. The best results were found for the Tracmor acceleromter, which at the time was not yet commercially available. A more recent systematic review by Plasqui et al. (2013) examined 25 recent accelerometer validation studies (between 2007-2011) again using DLW as the criterion standard. There were 18 different accelerometers assessed with the most valid accelerometer being the Actigraph, followed by Tracmor. There was large variability in terms of the types of accelerometers, how the output was presented and their validity in measuring daily PA. The authors also found that the additional use of other measures such as HR have not been shown to significantly improve EE estimations.

There have been many studies where accelerometers have been validated for use with children (Loprinzi and Cardinal, 2011). Sirard and Pate (2001) reviewed 17 studies in relation to accelerometry validation among children. They found that the studies that used indirect calorimetry had good positive correlations (mostly >0.7) with accelerometers. Pate et al. (2006) investigated the validation and calibration of the ActiGraph accelerometer using 3 - 5 year old children (n=30). The children wore the accelerometer and a portable metabolic stystem at rest and while performing structured activities in a laboratroy environment. Results showed that the accelerometer counts were highly correlated (r=0.90) with VO_2 measurements.

2.9.3.1 Validation of ActivPAL

Ryan et al. (2006) investigated the validity and reliability of the ActivPAL as a measure of walking. The test had two components; part one involved walking indoors on a treadmill at pre-determined speeds followed by part two which took place outdoors where participants walked at self selected speeds. Subjects wore two pedometers (Yamax Digi-Walker SW-200 and the Omron HJ-109-E) and the ActivPAL accelerometer. Video observation was used as the criterion measure. Results showed that the ActivPAL was both valid and reliable for measuring step number and cadence with an absolute percentage error of less than 1.2%. Accuracy was not adversely affected by walking speed or surface. Similarly, Maddocks, Petrou, Skipper and Wilcock (2008) examined the validity of three accelerometers (ActivPAL, PALlite and SW-401 Yamax Digi-Walker) during treadmill walking and travel in a motor car. Step counts were compared to video analysis of treadmill walking and a step count of zero for motor transport. For treadmill walking, the mean measurement error was <4% with no significant difference between the ActivPAL and PALlite. The Digi-Walker however was more likely to underestimate the number of steps taken and was significantly less accurate at speeds ≤1 m/s. In motor vehicle travel, both the PALlite and Digi-Walker measured steps erroneously (254 and 25 steps respectively), while the ActivPAL recorded no steps.

2.9.4 Reliability

Reliability is a pre-requisite of validity, thereby necessitating the appraisal of both (Welk et al. 2012). Reliability studies can use either mechanical devices or human trials and are defined using intra- and inter- monitor coefficients of variance (CV) and intraclass correlation coefficients (ICCC) (Chen and Bassett, 2005). Few of the studies reviewed by Sirard and Pate (2001) included information in relation to reliability. According to Welk (2005), companies perform calibration checks before releasing their units in order to ensure they are measuring and summarising the data in a similar way.

Reliability studies on accelerometers can be performed by comparing outputs from accelerometers, which are worn on opposite hips. Some studies have used mechanical shaker or oscillating devices to assess variation in accelerometer outputs (Trost, McIver and Pate, 2005).

2.9.4.1 Reliability of ActivPAL

Dahlgren et al. (2010) investigated the test-retest reliability of the ActivPAL in relation to step counts and found high to very high absolute and relative reliability for treadmill walking, and jogging activities at all speeds and stair walking, over time. The ICC values were moderate for both self-paced floor walking and cycling at 75rpms, however, for cycling at 45rpm and 60rpm the ActivPAL had poor absolute and relative reliability values. Oliver (2011) firstly compared directly observed steps with objectively measured steps from 3 pedometers (Yamax Digiwalker), accelerometers (Actical) and inclinometers (ActivPAL) in laboratory based setting. Secondly, the step counts were taken over a 48 hour period using all 3 devices. All devices accurately measured step counts in the laboratory, however, considerable disagreement was found in free living conditions. Results found that the ActivPAL was the most accurate for step-counts in free living, possibly due to the placement of the monitor on the upper leg.

A number of studies have also been carried out in relation to the reliability and validity of the ActivPAL among children and adolescents. For example, Davies et al. (2012) found that the ActivPAL had reasonable validity, practical utility and reliability for assessing posture and activity under free-living conditions with pre-school children aged 3-4 years. In New Zealand, Aminian and Hinckson (2012) found perfect correlations when comparing time spent sitting/lying, standing and walking among children (mean age 9.9 ± 0.3 years) with direct observation. Dowd, Harrington and Donnelly (2012) assessed the criterion and concurrent validity of the ActivPAL in adolescent females and found it to be a valid and reliable measurement tool for both PA and SB in this cohort.

2.9.5 Developing a Protocol for Accelerometer Use

Differences in calibration, practical use, data processing and reporting means that there are no standardised procedures for accelerometer use in research studies (Ward et al., 2005; Troiano, 2005). There are a number of reviews on the practical issues relating to accelerometer use (Trost et al., 2005; Ward et al., 2005; Berlin et al., 2006; Matthews et al., 2012). Appendix A reviews relevant research in relation to the various aspects of using accelerometers for research from choosing an appropriate device to data processing.

2.10 Measurement of Sedentary Behaviour

Sedentary Behaviour (SB) research has primarily used self-report measures in the past. However, according to Kozey-Keadle et al. (2011), no self-report tools can fully measure all aspects of SB. Additionally, many of the self-report instruments developed to measure SB and light intensity PA have not been validated (Pate et al., 2008). Atkin et al. (2012) presented an overview of the methods used to assess SB in population-based studies of both children and adults. They found great variation among self-report instruments in certain aspects such as recall period, question/answer design and how they were administered (i.e. interviewer or self-administered). They also found poor validity among self-report measures.

Therefore, researchers are now using objective measures such as accelerometers to accurately assess SB. However, as when measuring PA, it is important that cut points are established to accurately identify SB. Most studies have used cut off counts of less than 50 or 100 counts per minute; however, these cut points may not be applicable to all populations (Pate et al., 2008). Loprinzi and Cardinal (2011) state that accelerometers are useful for measuring SB in children as long as the cut points are appropriate to the audience being assessed and they recommend a sedentary cut-point of <100 counts per minutes for children and adolescents. While measuring SB using objective devices has its own challenges, Yildrim et al. (2011) recommend its use for SB measurement among children.

2.10.1 Using the ActivPAL in Sedentary Behaviour Measurement

The ActivPAL has been validated for assessing SB by Kozey-Keadle et al. (2011). In this study, inactive adult office workers (n=20) wore both the ActivPAL and the Actigraph accelerometers and were also directly observed for two 6-hour periods. During the second period, they were asked to reduce sitting time. The AP and the Actigraph under-estimated sitting time by 2.8% and

4.9% respectively; correlations between both methods and direct observation were r=0.94 and r=0.39 correspondingly. The authors concluded that the ActivPAL was more accurate and also more sensitive to reductions in sitting time and they recommended it be used in studies measuring SB. In Ireland, Harrington et al. (2011) examined sedentary levels and patterns in adolescent girls aged 15-18 years (n=111), using the ActivPAL and found it to provide accurate objective information for use to describe sedentary behaviour.

Reliability and validity studies using the ActivPAL for measuring sitting time are limited. Davies et al. (2012) found ActivPAL values for sitting/lying had 87% sensitivity, 97% specificity and 96% positive predictive value indicating its possible use for evaluating sitting time in children. While the ActivPAL does not measure the type of behaviour or the environment in which it occurs, Atkin et al. (2012) propose it to be a useful tool in the measure of SB in a variety of situations.

2.11 Summary

It is very evident that the prevalence of inactivity needs to be dramatically decreased worldwide. The benefits of PA for all, including children, adolescents, adults and older adults are well documented. Correlates research shows that both individual factors such as self-efficacy and social/cultural factors such as family support are important for PA participation. There is also a growing emphasis on physical environment correlates and policy level research with a view to creating conditions that are conducive for all people to become more active. Active travel is seen as a viable method of achieving PA daily. Some cities, such as Copenhagen in Denmark, have policies where cyclists and pedestrians receive precedence over the motor car thereby encouraging AT. However, policies such as this involve changing culture and peoples mindsets, and as such change will not happen overnight.

It is important that the levels of PA and AT are measured both objectively and subjectively so that a realistic picture of current levels of participation is captured. Therefore, if interventions are carried out, or new policy is developed and implemented, researchers and policy makers can actually see whether they make a difference.

Chapter Three

3.0 Methodology

3.1 Research Design

The purpose of this study was to measure physical activity (PA), sedentary behaviour (SB) and active travel (AT) both objectively and subjectively through a cross-sectional analysis of 13-16 year old secondary school students in County Carlow. Data collection was carried out in September and October 2012. The study involved the collection of self-report data on PA levels in school and during leisure time, active travel habits and attitudes to active travel on a sample of 2nd and 4th year post primary school-going adolescents (13-16 years). Physical activity and sedentary behaviour was also measured objectively on a sub-sample of students using an ActivPAL accelerometer. This chapter will summarise the methods used for the recruitment of participants, provide details of the measurement protocols adhered to and will outline the statistical analysis undertaken on the data collected.

3.2 Participants and Sampling

3.2.1 Schools

According to the Department of Education and Skills (2014), there are 723 post-primary schools in Ireland made up of secondary, vocational, community and comprehensive schools. There are a total of 359,047 post-primary school students (49.7% male, 50.3% female). In County Carlow, there are 11 post-primary schools (five secondary, five vocational and one community) with a total of 5,856 students (49.3% male, 50.7% female). There are four post-primary schools in Carlow Town; one boy's school, one girl's school and two mixed sex schools. For this study, a convenience sample from one all-girls secondary school (total 913 students) and one all-boys secondary school (total 551 students) in Carlow Town were recruited. Convenience sampling is a non-probability sampling technique where participants are selected because of ease of access to the researcher (Gravetter and Forzano, 2012).

A letter was delivered to the principals of each school, (Appendix B) which outlined the components of the research, the benefits of participation and what would be involved for the school if they agreed to take part in the study. The researcher followed up with a phone call to the PE teachers at each of the schools and arranged a meeting once interest was confirmed. Plans for data collection were made with the PE teachers and information letters and consent forms (Appendix C) were given to the PE teachers for distribution.

3.2.2 Participants

Eligible participants for this study included second and transition year students in each school chosen primarily because these are not examination years. Nationally, there are 56,032 second year and 32,673 transition year students in post-primary school. In this study, there were approximately 140 girls in second year, 125 girls in transition year and 100 boys in second year and 50 boys in transition year. Every student in 2nd and 4th year (n=415) was invited to take part in the self-report element of data collection. The final questionnaire sample consisted of n= 362 participants (aged between 13-16, 62% girls, 38% boys) all of whom completed the self-report questionnaire. There were no non-consenting students, so all students who were present on the day of data collection completed the survey. A sub-sample of the 362 participants took part in the second component of the study, which involved the objective assessment of PA and SB using accelerometers. Specifically, one class from each of the year groups were randomly selected to participate in this phase. Out of the total available to wear the accelerometers (n= 96), there were 18 students who did not consent. All other students were recruited as participants (n= 78, 49% boys, 51% girls aged between 13-16 years)

3.3 Variables

3.3.1 Subjective Measure - Questionnaire

The current study used a self-report survey with 6 sections (Appendix D), combining validated self-report measures along with questions on demographics and active commuting.

3.3.1.1 Demographics

Participants were requested to provide their age and year in school. Sex was not requested as the two schools surveyed were single-sex schools and questionnaires were kept separate until they were coded and the data inputted. For this research 13-14 and 15-16 year olds were grouped together to form two age categories.

3.3.1.2 Physical Activity

Participant's current PA behaviour was assessed using the International Physical Activity Questionnaire for Adolescents (IPAQ-A), which asked for detail on all physical activities performed over the previous seven days. The survey was divided into the following four sections:

- Physical activity during school time. This was broken down into the number of classes of PE/time spent during PE and the amount of time spent doing vigorous, moderate and walking activity during breaks in school.
- Number of days and time spent doing physical activities in and around the home such as housework and gardening
- Transport physical activity which was divided into number of days and time spent travelling by motor vehicle, bicycle, and/or on foot.
- Time spent doing vigorous, moderate and walking activity during recreation, sport and leisure-time.

3.3.1.3 Travel to School

To classify participants as active/inactive commuters, students were asked how they usually travelled to school (for the longest part of their journey). These questions were adopted from the CSPPA study (Woods et al., 2010). Four options were presented in the questionnaire, however during data collection it transpired that some students took the train and these students were allowed to add this option when completing the survey. The options for travel to school were walk, cycle, car, bus and train. The first two options were classified as active commuting while the latter three were classified as inactive commuting (Woods et al., 2010).

Additionally, this section asked how students would prefer to travel to school, the length of time it took to get to school and whether they owned or had access to a bicycle. Participants were also asked if they could estimate the distance (km) between their home and the school. This data was used to compare estimated and actual distance travelled to school. The steps taken to calculate the actual distance travelled are detailed in Appendix E.

3.3.1.4 Perceptions of Active Travel

The questions on this part of the survey were based on a questionnaire developed by Emond and Handy (2012) in conjunction with pupils in a school environmental club in Davis California and were designed to measure the possible factors that influence walking/bicycling to school, such as comfort, practicality, and peer and parental influences.

3.3.2 Objective Measure - Accelerometer

3.3.2.1 Physical Activity

PA measured by accelerometer was quantified in terms of intensity, duration and steps. Intensity was divided into light and moderate-to-vigorous physical activity. Light intensity activities include slow walking and light housework while moderate-to-vigorous activities are those that increase the breathing rate and include activities such as fast walking, jogging and housework that might involve intense cleaning. Duration of physical activity was measured as minutes per day. PA was also measured in terms of steps per day.

3.3.2.2 Sedentary Behaviour

Pate et al. (2008) define sedentary behaviour (SB) as "activities that do not increase energy expenditure substantially above the resting level and includes activities such as sleeping, sitting, lying down, and watching television and other forms of screen-based entertainment". In this study, SB was quantified in terms of frequency and duration. Frequency was measured in bouts; i.e. the number of times per day a person was in a seated/lying position and also the duration of these bouts, measured in hours per day. Duration related to the length of time spent in these sedentary bouts. Breaks in sedentary activity, which involved moving from a seated/lying position to upright, were also measured and expressed as number and duration of breaks (minutes).

3.4 Instruments

3.4.1 Questionnaire

3.4.1.1 Physical Activity

Physical activity data were collected using the IPAQ-A measurement tool. The International Physical Activity Questionnaire (IPAQ; www.ipaq.ki.se) was developed for assessing physical activity and activity levels across the world. A long and short version of the IPAQ was pilot tested and evaluated across twelve countries by Craig et al. (1993). Participants in the reliability study completed the IPAQ twice, one week apart while those in the validity study also completed the questionnaires twice and wore a motion detected for one week between completing the questionnaires. This reliability and validity study presented correlations of about 0.80 for reliability and 0.30 for validity showing that the IPAQ as a measurement tool is at least as good as other methods of physical activity self-report. Other studies have also since investigated the reliability and validity of IPAQ. For example, Deng et al. (2008) examined the reliability and validity of the IPAQ-Chinese and found 'good reliability'. In New Zealand, Boon, Hamlin, Steel and Ross (2010) conducted a validation study of both the New Zealand Physical Activity Questionnaire (NZPAQ) and the IPAQ with accelerometry and found both to have acceptable validity in comparison to data acquired using the ActiGraph accelerometer.

The current study used questions taken from the adapted version of the IPAQ; the IPAQ-A (International Physical Activity Questionnaire for Adolescents). The main difference between the IPAQ and IPAQ-A is that questions about PA at work are replaced with questions about PA in school. There are also fewer questions about household activities. Hagstromer et al. (2008) found reasonable validity between the IPAQ-A and accelerometry in measuring physical activity in older adolescents aged 15-17 years (R_s=0.17–0.30, $P<0.05$); however, no significant correlations were found for the younger, 12-14 year age group. Ottevaere et al. (2011b), in a related study, also found similar correlations, but for both age groups between the IPAQ-A and Actigraph accelerometers. They also found that measures were most comparable for vigorous intensity activity.

3.4.1.2 Perceptions of Active Commuting

The questions on this part of the survey were based on a questionnaire developed by Emond and Handy (2011) in conjunction with pupils in a school environmental club in Davis California. To date, no studies have been done on the validity or reliability of this questionnaire. The survey consists of 21 cycling and 16 walking agree-disagree statements which are measured using a 5-point Likert scale from agree-strongly to disagree strongly. The ecological model of health behaviour was used as the conceptual model for the study. This model proposes that behaviour is influenced by a number of different factors including the individual, social and physical environments (Sallis and Owen, 2002). For both cycling and walking, statements were divided into one of the following categories as outlined by Emond and Handy (2011):

1. *Individual Factors - Mode Preference*
2. *Individual Factors - biking comfort*
3. *Individual Factors - other cognitive factors*

4. *Individual Factors - practical issues*
5. *Social-environmental factors - peers*
6. *Social-environmental factors - parents*
7. *Physical-Environment factors*

3.4.2 Accelerometer

Accelerometers are small unobtrusive measurement devices, which provide an objective assessment of physical activity by recording bouts of physical activity. Reviews of accelerometry have shown their use to be precise in terms of measurement of physical activity during all intensity levels – from sedentary to vigorous (De Vries et al., 2006; Biddle et al., 2010). The device chosen for this study was the ActivPAL™ (PAL Technologies Ltd., 141 St James Road, Glasgow G4 0LT, United Kingdom, http://www.paltechnologies.co.uk). The ActivPAL is worn on the midline of the thigh and contains a uni-axial piezoresistive accelerometer which produces and records signals based on thigh inclination. It can, therefore, record the amount of time spent sitting/lying, standing, and walking thereby allowing for the measurement of both activity and inactivity. It also shows the duration of these events, number of steps per day and the cadence of walking periods (Grant et al., 2006). The ActivPAL weighs 15g and is capable of recording over seven days continuously. Data is recorded in 15-second bouts called epochs. Data is then classified by the ActivPAL Professional Research Edition (Version 6.3.0) into the following categories: sit/lie, stand and walk (including number of steps taken and activity intensity. This data is recorded using algorithms, which can then be downloaded and converted to an Excel document and into SPSS for further analysis (Taraldsen et al., 2011).

A number of validation studies have taken place on the ActivPAL accelerometer. For example, Grant et al. (2006) found it to be both a valid and reliable device for recording posture and activity. In the study, 10 participants wore three ActivPAL accelerometers whilst performing a number of everyday activities. Data was also captured by digital camera and observations of these recordings independently by three observers were used as the reference method. Maddocks et al. (2010) validated the accuracy of ActivPAL and two other accelerometers in a study of treadmill walking and motor vehicle travel. The authors concluded that the ActivPAL accurately measured step count at various walking speeds and unlike the two other accelerometers, was not triggered mistakenly by motor vehicle travel ($p<0.01$). Another recent study on adolescent girls recommended the use of accelerometers and in particular the ActivPAL, for measuring sedentary behaviour (Harrington et al., 2012).

3.4.2.1 Development of an Accelerometry Protocol

The following accelerometer protocol used in the current study was based on that used by Harrington et al. (2011).

Placement of Accelerometer

As per the manufacturer's instruction, the ActivPAL is placed on the mid-point of the anterior right thigh.

Number of Days Monitoring

The ActivPAL is capable of recording 7 days continuously and participant data was included in the results if there were a minimum of 4 days, including one weekend day recorded. Therefore, where possible, 7 days of recording were collected with the first day of data discarded because it was not a complete data set for the first day and also to minimise reactivity to wearing the monitor.

Number of Minutes per Day

The ActivPAL can be worn for 24 hours a day and participants were asked to wear the accelerometer throughout the entire day, where possible. The minimum number of minutes recorded for a day to be considered valid was 600mins (or 10 hours) during a typical day (between 7am - 11pm).

Classification of non-wear time

To improve accuracy in the calculation of accelerometer variables, non wear time (if present) was manually removed. Non-wear time was classified as 60 consecutive minutes or more of consecutive 0 counts between the hours of 7am and 12pm. This time was then subtracted from the overall wear time. It was also subtracted from sedentary bouts of > 60 minutes.

Epoch Length

Early studies using accelerometers used 1 minute epoch lengths, however, this was found to be too long for use with children because of the sporadic nature of their activities (Trost et al., 2005). Recent studies have used 15 second epochs with children and adolescents (Harrington et al., 2011; Yildrim et al., 2011; and Ridgers et al., 2012). The current study measured counts over a 15 second epoch.

Cut Points Used

Thresholds of 2997 and 8229 counts were used for moderate PA and vigorous PA respectively as identified by Dowd et al. (2012) to be the optimum for both sensitivity and specificity. Light intensity activity was calculated by subtracting MVPA from stepping time. The inclinometer function of the ActivPAL was used to identify sitting/lying and standing time.

3.4.2.2 Interpretation of output (graphs, daily/weekly summaries, counts)

Data output from the ActivPAL comes in different forms:

1. Graphical display of daily activities with summary variables (steps, upright events, seated/lying events)
2. Raw data files (excel) containing data by week, day and hour of time spent sitting/lying, standing and stepping and sit-to-stand transitions. There is also an Excel file with a full week of accelerometry counts per 15 second epoch.

3.5 Data Treatment

3.5.1 Data Storage and Entry

All questionnaire data were stored and analysed using SPSS (Statistical Package for Social Sciences; IBM Version 20). Each questionnaire was given a unique code. Once data was entered into the database, it was checked for incomplete, missing or incorrect data.

3.5.2 Physical Activity Data Cleaning and Preparation

3.5.2.1 Questionnaire

Data that was missing was given a value of 999. The data was then treated according to the IPAQ Scoring protocol (Revised November 2005; www.ipaq.ki.se) which outlines the guidelines for processing and analysing data from IPAQ (Long Form). All data that was provided in hours and minutes were converted into minutes. Minutes at each intensity exceeding 180 minutes daily were truncated to 180, to remove extreme outliers. Responses of less than 10 minutes were re-coded to zero (based on the rationale that scientific evidence has shown that for health benefits to occur, at least 10 minutes of PA are required). Cases in which the sum of all walking, moderate and vigorous time variables were greater than 960 minutes were excluded from the analysis. Data over 180 minutes and less than 960 minutes were truncated to 180 minutes. Daily minutes and weekly minutes were calculated for all domains and intensities. To calculate weekly minutes, the minutes per day were multiplied by the number of days. Daily averages were then calculated by dividing the weekly minutes by 7 (for leisure, transport, housework and gardening variables) or 5 (for PE and break time variables; because they occurred during school time).

Domain sub scores for school were calculated by adding the total weekly PE minutes, total break minutes (which was the sum total of walk, moderate and vigorous intensity break minutes). For total recreation minutes weekly, the total walk, moderate and vigorous recreation minutes per week were summed. The total transport minutes weekly consisted of the total walk and bike transport minutes per week. Intensity sub-scores were calculated as follows; walking during break time, for transport and for recreation minutes were all added together to give total walking time (minutes/week). Moderate intensity minutes were calculated by summing PE, housework and gardening, moderate intensity break time activity and bike transport minutes per week. Finally total vigorous intensity minutes were computed by adding vigorous break time activity and vigorous recreation minutes weekly. To determine the total physical activity minutes per week each of the total walking, moderate and vigorous minutes weekly were summed. MVPA values were calculated by adding the moderate and vigorous minutes together. Any scores of 60 minutes or over were deemed to meet the recommended guidelines for physical activity, which according to the Department of Health and Children (2009) are that children and young people need at least 60 minutes of MVPA daily. Overall figures for active travel were calculated by adding time spent walking and cycling for transport. *Table 3* displays a summary of the outcome variables and how they were calculated.

Those who walked and cycled to school were grouped together (active travel to school) while those who travelled to school by car, bus or train were combined (motorised travel).

Table 3

A summary of the IPAQ-A outcome variables and how they were calculated

Outcome Variable	Component Variables
Total School Minutes	PE minutes + total break minutes (including walk, moderate and vigorous intensity break minutes)
Total Recreation Minutes	Sum total of walk, moderate and vigorous recreation minutes
Total Transport Minutes	Total walk transport + total bike transport
Intensity – Walking	Walking during break time + walk for transport +walk for recreation
Intensity – Moderate	PE time + housework and gardening + moderate intensity break time +bike transport
Intensity – Vigorous	Vigorous break time + vigorous recreation time
Total PA Weekly	Walking + Moderate + Vigorous minutes
MVPA Weekly	Moderate + Vigorous minutes
Total Active Transport	Bike transport + walk transport minutes

3.5.2.2 Accelerometer

Physical Activity

ActivPAL proprietary software (ActivPAL™ Professional V6.4.1) was used to download the objectively recorded data into a Microsoft® Office 2007 Excel spreadsheet using the option 'save results by epoch' tab. This output was in the form of raw counts every 15 seconds (epoch). This file contained step counts, posture transitions, an MET score and the number of seconds each person spent upright, stepping , and sedentary, per 15s epoch. Daily totals were computed using a Microsoft® Office 2007 Excel template developed in the University of Limerick. The template was copied into column J of the epoch file at 6:59:45 on day 2 (as data from day 1 is discarded). Information calculated from the template included time spent sedentary, light physical activity, MVPA and number of steps per day. Thresholds of 2997 and 8229 counts were used for moderate and vigorous physical activity respectively as established by Dowd et al. (2012).

Sedentary Behaviour

The total time spent sedentary was also calculated from the template outlined in the physical activity section above. The ActivPAL is unique in that it contains an inbuilt inclinometer which allows inclination of the thigh to classify sitting/lying/standing without using thresholds (Dowd et al. 2012). Further analysis of sedentary behaviour was carried out using a customised MATLAB (Version R2014a) program developed by Dowd et al. (2012). The output from this programme was a Microsoft® Office 2007 Excel spreadsheet which indicated sleep time and gave a breakdown of daily sedentary time and non-wear time. Non wear time was classified as 60 minutes or more of consecutive zero accelerometer counts between the hours of 7am and 11pm and was manually subtracted from daily total sedentary time. Total sedentary time during waking hours was calculated by subtracting sleep and non-wear time from the total sedentary time. The time spent sedentary after waking and before bed time was then copied into another Microsoft® Office 2007 Excel template which calculated the total number and time in minutes spent in sedentary bouts in categories of <5, 5 – 10, 11 – 20, >20, >30, >40 and >60 (bouts and minutes). For the purpose of analysis, bouts and time categories <5, 5 – 10, 11 – 20 were re-categorised as 0 – 20 minutes.

Breaks in sedentary time i.e. changing from a sitting/lying position to an upright one, were calculated using a custom developed Microsoft® Office 2007 Excel template, again using the time after waking and before bed. Both the number and duration of breaks were calculated. In addition, time categories of <5, 5-10, 11-20 and > 20 minutes were also computed along with maximum break time, minimum break time, and average break time (all in minutes).

Reporting the data

ActivPAL data weres reported as:

- Steps per day
- Total physical activity per day

- Breakdown of light and MVPA
- Sedentary Behaviour (bouts and breaks and total time spent sedentary per day).

3.6 Ethical Approval

In accordance with Waterford Institute of Technology regulations, a research proposal detailing the proposed methodology was submitted to the Research Ethics Committee. Ethical approval was granted in March 2012. To recruit schools to take part in the study, permission was first sought from the Board of Management via a letter to the school principal. Following school consent, permission to participate in both the questionnaire and accelerometer part of the study was collected from parents. Specifically, a letter was sent home to parents outlining the details of the project and how they could withdraw or allow their child to participate. To withdraw from the study, parents signed the letter and returned it to school. Non-return of the letter reflected passive consent. Students selected to participate in the accelerometer part of the study signed their own written informed consent sheet (Appendix G) and were given additional information for their parents (Appendix H), which also outlined their option to withdraw at any stage, should they decide to do so.

Prior to data collection, participants were informed of the purpose of the study and were assured that all data was collected anonymously and that no student would be identifiable. Additionally, only individuals involved with the research had access to the data. All students were explicitly informed about their right to withdraw from the study at any point of the data collection process.

3.7 Data Collection Procedures

3.7.1 Accelerometer Data Collection

The procedure for data collection via accelerometer was as follows:

1. Students were given a brief outline of the study, including information on the accelerometer and its function (Appendix F).

2. Consent forms were then distributed signed and collected.

3. Letters were given to participants for their parents/guardians outlining the research study, and providing information on the accelerometers and their use.

4. Participants were instructed on how to wear the accelerometer and when to take it off.

5. The researcher either left the room, or where feasible, allowed students to go to the changing rooms/toilets to attach the accelerometer to their right thigh.

6. Participants were given an information sheet which included frequently asked questions in relation to accelerometer use.

7. They were also given a log sheet to note when they removed and re-applied the accelerometer.

8. Participants were given the opportunity to ask questions.

9. The researcher left when all participants were satisfied with the placement of the monitor and their instructions for the following week

10. After seven days of continuous wear the researcher returned to collect the monitors and to get participants to fill out the self-report survey on their previous 7-days of physical activity.

3.7.2 Questionnaire Data Collection

Questionnaire data collection took place at the end of the accelerometer recording period. The procedure was as follows:

1. The project was outlined to all the students and they were given the choice to participate.

2. The researcher provided instructions on how to complete the questionnaire and guaranteed the confidentiality of each student's responses (the child’s name did not appear on the questionnaire and the child was not identifiable in any way). Students were advised to answer all questions if possible.

3. Students were given the opportunity to ask questions.

4. The questionnaires were handed out to each consenting student.

5. Participants were given as much time as was needed to complete the questionnaire.
6. Once the questionnaires were completed, they were collected by the researcher.

3.8 Data Analysis

Descriptive statistics were used to summarise the time spent being active including patterns, domains and intensity of activity. Sedentary behaviour was also analysed using descriptive statistics to summarise time spent sedentary, number of bouts and breaks in sedentary time. These scores were compared across sex and age. Inferential statistics, using both parametric and non parametric tests, were then used to assess significant differences in activity and sedentary behaviour between boys and girls and age groups. Independent t-tests were used for data that was normally distributed while the Mann-Whitney test was used for data that was skewed. Skewness scores were generated using descriptive statistics and assessed that with the aid of a histogram analysis.

Correlations were used to investigate relationships such as that between sedentary breaks and PA, objective versus subjective measurement methods, active travel and physical activity. Pearson correlations were used for data that was normally distributed, while Spearmans Rho correlations were used for data that was skewed. Paired sample t-tests were used to determine the significance between the two measurement methods. The Bland Altman method was used to examine the level of agreement between the questionnaire and accelerometer in recording time spent in overall PA and MVPA. The Bland Altman is a scatterplot with the mean values on the horizontal axis and the differences between the mean values on the vertical axis; thereby illustrating the amount of disagreement between the measures. The Bland Altman method was also used to compare the actual versus estimated distance to school.

3.9 Aim

The main aim of this study is to validate and measure PA, SB and AT in second level students

3.10 Research Questions

a) What is the physical activity profile, and sedentary behaviour profile of school-going male and female adolescents?

b) Is there a relationship between data collected objectively using the ActivPAL accelerometer and subjective data collection using the IPAQ-A questionnaire in school-going adolescents?
c) What is the active travel profile of second-level students?
d) Do active commuters and non-active commuters have accurate perceptions of travel distance to school?

3.11 Chapter Summary

This chapter has outlined the both the study population and research methods used. Details of data collection and treatment, instruments used and statistical analysis performed are also outlined. The next chapter will present the results of the study.

Chapter Four

4.0 Results

This chapter will present the main findings divided into four sections to address the research questions outlined in section 3.9. Section 4.1 will examine the physical activity (PA) profile of second level students based on the data gathered from the IPAQ-A questionnaire. Section 4.2 will focus on PA and SB data gleaned from the ActivPAL accelerometer. Section 4.3 will investigate the relationship between the questionnaire and accelerometer data results. Finally, section 4.4 will concentrate on the analysis of active travel data.

4.1 PA Behaviour - IPAQ-A Data

This section will examine PA behaviour from data collected using the International Physical Activity Questionnaire for Adolescents (IPAQ-A). Overall PA patterns and a breakdown of PA at different intensities and domains will be analysed. PA participation will also be assessed as daily MVPA.

4.1.1 Description of Participants

In total, 362 adolescents (61.9% girls, 38.1% boys) completed the IPAQ-A. The mean (±SD) age was 14.23 ± 1.16 years (range 13-16 years). Second year students made up 64.1% of the participants, with the remaining 35.9% in fourth (transition) year in school. Participant characteristics are presented in *Table 4*.

Table 4

Participant Characteristics

	% (n) Girls	% (n) Boys
Total	224	138
Age		
- 13	18.6 (67)	8.6 (31)
- 14	19.1(69)	17.2 (62)
- 15	14.1 (51)	6.6 (24)
- 16	10.1 (37)	5.5 (21)
Year		
- 2nd	37.6 (136)	26.5 (96)
- 4th	24.3 (88)	11.6 (42)

4.1.2 Overall PA Patterns

In most cases the distribution of PA data was considerably skewed so the median values and interquartile ranges are used to present results. However, the mean, standard deviation and median (min/week) self-reported scores for the different domains and intensities based on gender and age are given in Appendix I. Overall, participants reported a median (IQR) of 129.29 (136.18) mins/day of total PA (walking, moderate and vigorous combined). Boys reported significantly more PA than girls (median 155.5, IQR 121.79 and 113.13, IQR 120.32 min/day respectively, p = .000). The 15-16 year old cohort participated in almost 30 minutes more PA daily than the younger age group, however, this difference was not significant (p=.055). *Figure 2* shows the difference between each of the age groups by gender, with both female age groups participating in less total PA than their male counterparts (p = .004 for 13-14 year olds and p = 0.006 for 15-16 year olds).

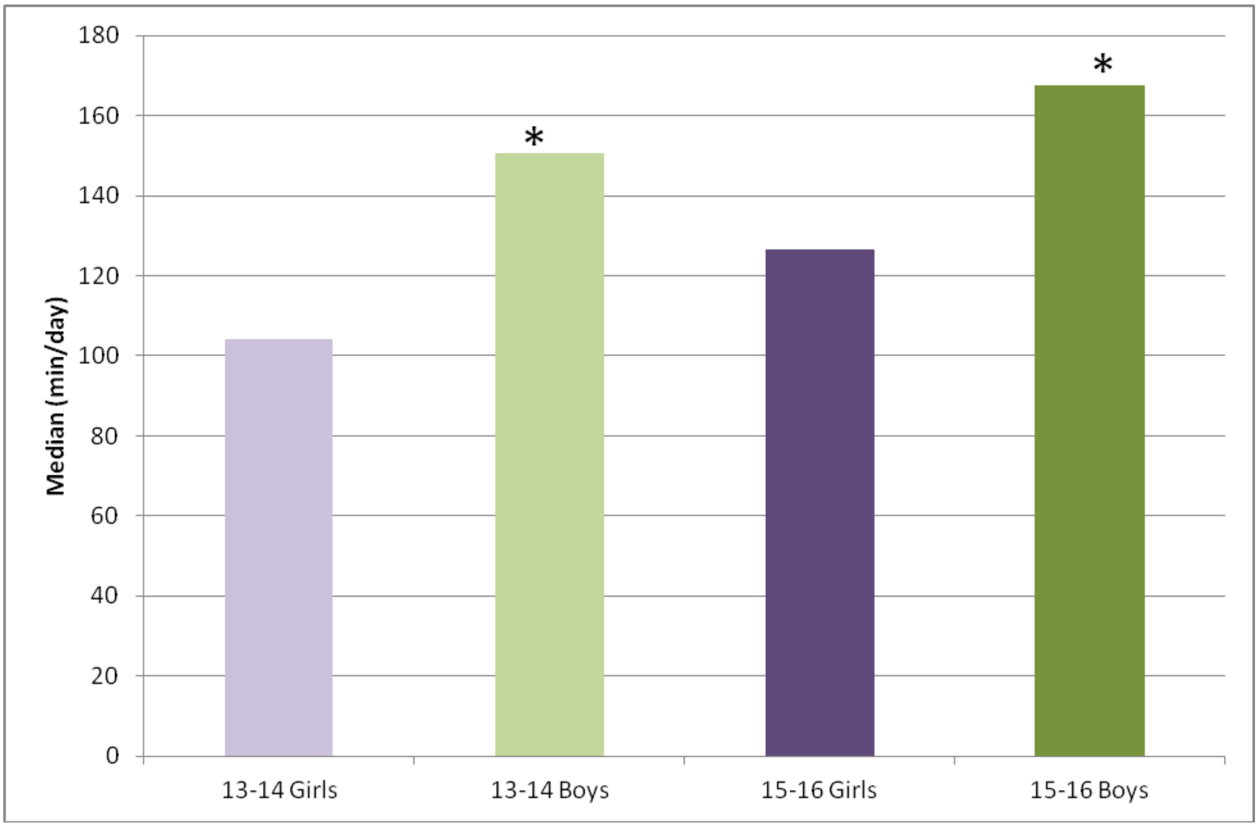

Figure 2

Gender/age comparison of total PA (mins/day). * Significant difference (p<.05)

4.1.3 PA Intensity

Adolescents reported spending most of their time in moderate PA (54.07, IQR 67.25 min/day or 46.4% of total PA), less in walking (42.86, IQR 59.75 min/day or 36.7% of total PA) and the least amount doing vigorous PA (19.7, IQR 35.35 min/day or 16.9% of total PA). *Table 5* outlines the median and interquartile ranges for PA intensity by gender, age and gender/age combined. Boys spent significantly more time walking and in moderate PA than girls (p=.001 and p=.000 respectively). There was no significant difference between the age groups in terms of moderate and vigorous PA, however, the 15-16 year old group spent more time walking daily than their younger counterparts (p=.004). 13-14 year old boys spent more time walking and in moderate intensity activity than their female counterparts (p = .004 and p = .010 respectively), while 15-16 year old boys spent almost 28 minutes more time in moderate PA daily than 15-16 year old girls (p=.004).

Table 5

Median Time Spent in PA of Different Intensities (mins/day)

	Total Median (IQR)	n	Walking Median (IQR)	n	Moderate Median (IQR)	n	Vigorous Median (IQR)	n
Boys	155.50 (121.79)	106	55.50 (77.89)	96	65.86 (76.29)	105	23.57 (30.11)	106
Girls	113.13 (120.32)	218	38.14 (56.40)	198	45.86 (66.43)	216	17.79 (36.00)	218
p	.000**		.001**		.000**		.357	
13-14 years	117.00 (138.07)	197	36.00 (54.07)	174	52.71 (67.86)	195	21.42 (36.00)	197
15-16 years	146.86 (116.0)	127	52.29 (55.71)	120	61.14 (64.57)	126	17.14 (30.86)	127
p	.055		.001*		.972		.403	
13-14 Girls	104.00 (118.5)	132	30.00 (48.96)	116	44.29 (66.29)	131	22.29 (36.54)	114
13-14 Boys	150.57 (156.86)	65	46.29 (72.8)	58	60.00 (77.71)	64	21.43 (31.71)	51
p	.004*		.004*		.010*		.949	
15-16 Girls	126.43 (117.36)	86	47.86 (53.21)	82	48.43 (68.34)	85	13.86 (29.36)	78
15-16 Boys	167.43 (90.50)	41	68.86 (85.71)	38	75.71 (72.71)	41	25.71 (29.57)	36
p	.006*		.057		.004*		.157	

**p<0.01* p < 0.05

4.1.4 PA Domains

The total sample reported most PA during their school time (PE and break time, median 47.50 min/day or 44.5% of sum of all domains), leisure time accounted for 29.29 min/day or 27.4%) and active travel accounted for 17.14 min/day or 16.1%. Housework and gardening contributed least to overall PA (12.86 mins/day or 12.0%). *Figure 3* illustrates the time spent in the various domains stratified by gender/age.

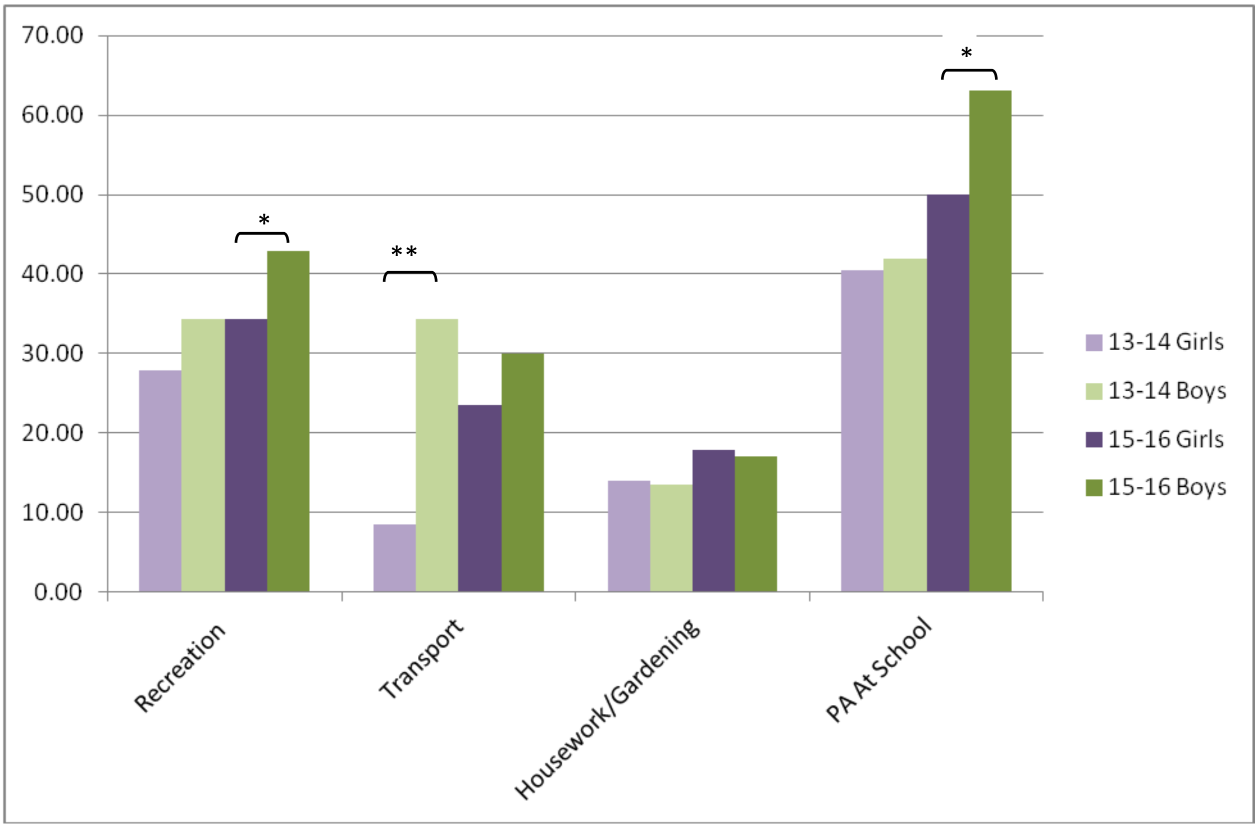

Figure 3

Gender/age comparisons of PA across different domains; recreation, transport, housework/gardening and PA at school. Significant difference: * p<.05; ** p<.001

4.1.4.1 PA at School

Girls spent a median of 43.5 (IQR 50.00) mins/day in PA at school (PE and break time combined) while for boys, this figure was 53.00 (IQR 59.80), (p=.066). There was no significant difference in school based PA between age groups (p=.155). However, 15-16 year old boys spent nearly 13 more minutes in PA at school than 15-16 year old girls (p=.039). No significant difference was found between 13-14 year old boys and girls.

The overall break time PA at school was 36.00 mins/day (IQR 42.00). There was no significant difference found between genders, age or gender/age combined. However, as can be seen from *Table 6*, there were significant differences between boys and girls, age groups and gender/age combined when it came to PE time in school. Boys spent considerably more time in PE class than girls, both overall and when broken down into age groups. The 15-16 year old age group also participated in twice as much PE time than their younger counterparts.

Table 6

Physical Education (PE) at school (median mins/day)

	n	Median (IQR)	p
Overall	291	12.00 (9.00)	
Girls	199	8.00 (7.00)	.000**
Boys	92	16.00 (9.5)	
13-14 Years	182	7.00 (9.25)	.008**
15-16 Years	109	14.00 (6.00)	
13-14 Girls	123	7.00 (1.00)	.000**
13-14 Boys	59	16.00 (10.00)	
15-16 Girls	76	14.00 (4.00)	.049*
15-16 Boys	33	24.00 (18.00)	

**p<0.01* p < 0.05

4.1.4.2 Leisure Time PA/Recreation

The overall median leisure time PA was 29.29 (IQR 38.57) mins/day. Boys spent an average of 37.50 minutes daily (IQR 32.14) while girls spent 25.71 (38.57 IQR) in leisure time PA (p=.068). There was no significant difference between the age groups (p=.113) or between 13-14 year old boys and girls (p=.600). However there was a significant difference between the 15-16 year olds with boys participating in over 16 minutes more leisure time PA daily than girls (p=.015).

4.1.4.3 Transport PA

Overall, adolescents spent 17.14 (IQR 63.21) minutes daily using their bikes or walking to get somewhere. Significant differences were found between gender, age, and between 13-14 year old boys and girls (p = .001, p = .014 and p =.000 respectively; *Figure 4*).

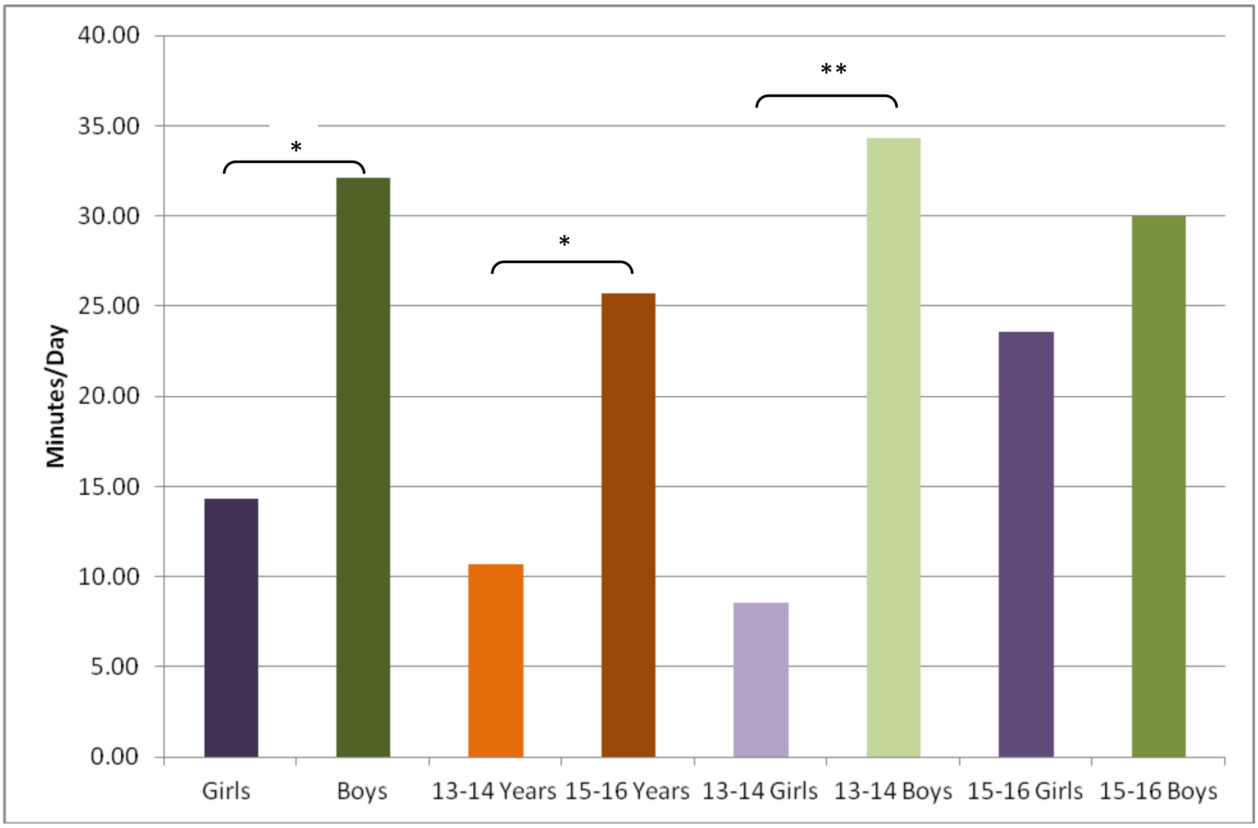

Figure 4

Gender, age and gender/age comparisons of active travel daily (median mins/day). * p<.05; **p<.001

4.1.4.4 Housework Gardening PA

Median daily minutes spent doing housework and gardening was 12.86 (IQR 38.57) mins/day. There was no significant difference for gender, age or gender/age combined.

4.1.5 MVPA Daily and Meeting the Guidelines

The average (median) daily MVPA amongst all participants was 58.93 minutes (IQR 67.14). *Figure 5* below shows that there was a significant gender difference in daily MVPA (boys > girls, p=.011) while15-16 year old boys participated in 72.86 (IQR 57.50) mins/day MVPA compared to 57.50 (IQR 60.36) mins/day for 15-16 year old girls (p = .024). There was no significant differnce between the age groups (p = 0.764) or between the 13-14 boys and 13-14 girls (p=.117).

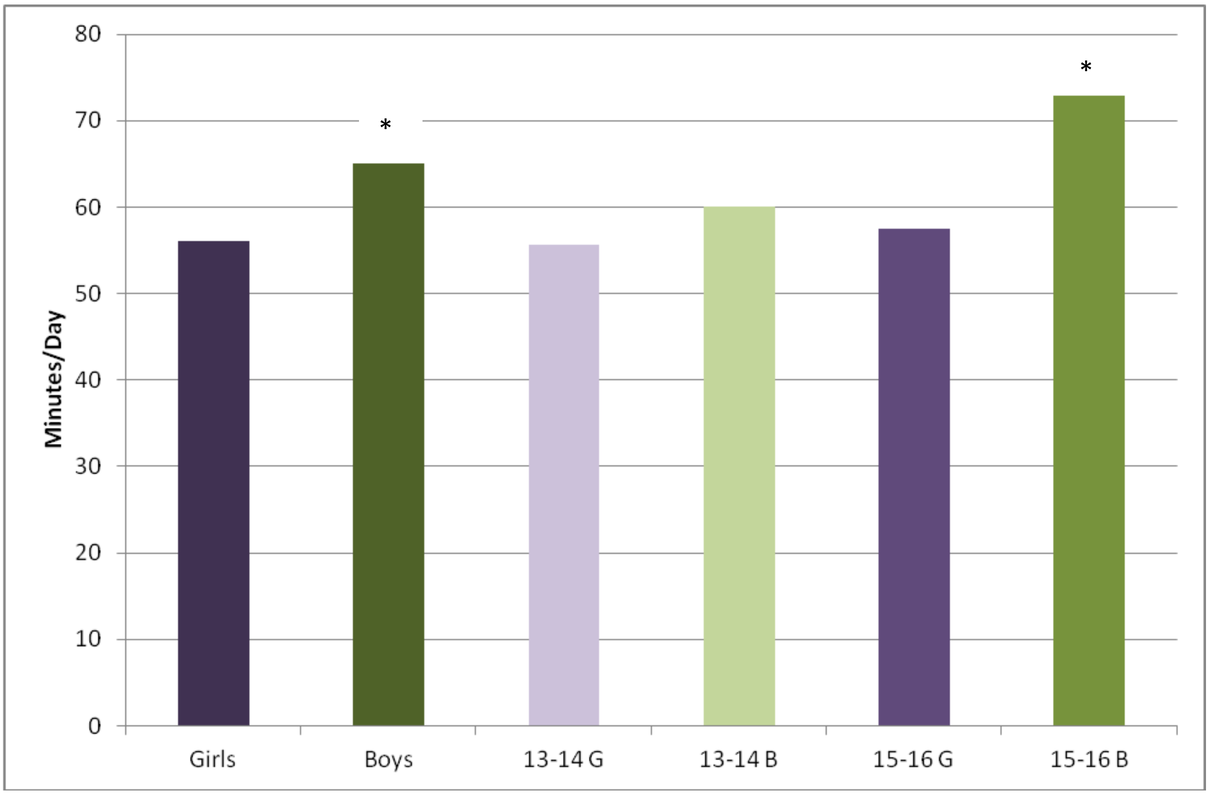

Figure 5

Gender and gender/age comparisons of average daily MVPA. * p <.05

Participants were categorised as either meeting or not meeting the PA guidelines based on the Department of Health and Children (2009) recommendations that children and young people should participate in at least 60 minutes of MVPA daily. As can be seen from *Figure 6*, 49.8% of participants accumulated at least 60 minutes per day of MVPA.

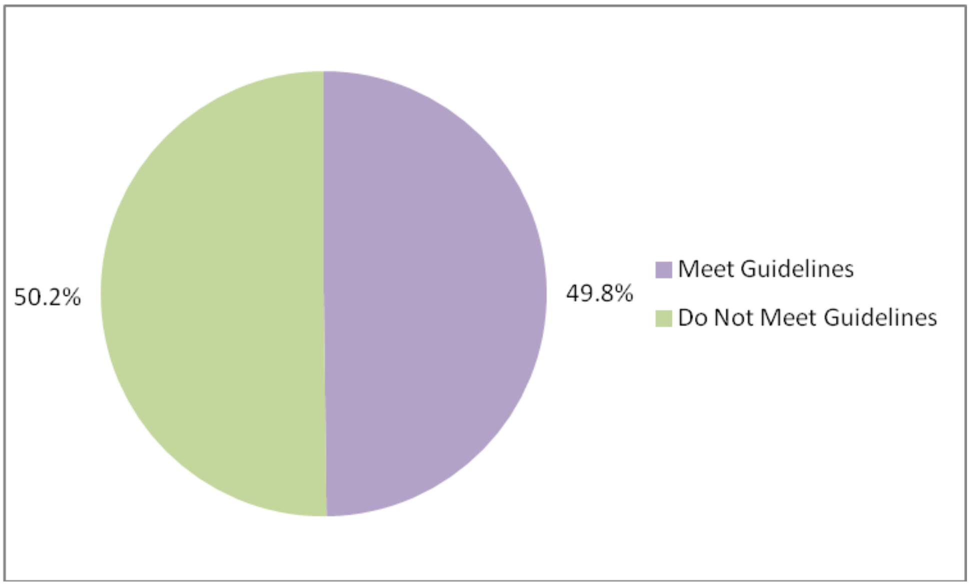

Figure 6

Percentage of participants who met the PA guidelines

A breakdown of the number of participants meeting the PA guidelines by gender, age and gender/age combined is shown in *Table 7*. Almost 7% more boys met the guidelines than girls, however, this difference was not significant.

Table 7

Percentage of students meeting the daily PA guidelines

	% >60 mins (n)	**p**
Girls	46.8 (102)	.111
Boys	53.2 (58)	
13-14 year olds	48.7 (95)	.698
15-16 year olds	51.2 (65)	
13-14 year old girls	47.0 (62)	.416
13-14 year old boys	53.2 (33)	
15-16 year old girls	46.5 (40)	.127
15-16 year old boys	61.0 (25)	

4.1.6 Summary of IPAQ-A PA Trends

The mean, standard deviation and median (min/week) self-reported scores for the different domains and intensities based on gender and age are given in Appendix I. Boys spend more time in PA across all domains and intensities. School is where the greatest amount of PA takes place. Most PA takes place at moderate intensity for both boys and girls. The highest total PA minutes are among 15-16 year old boys, followed by 13-14 year old boys with the 13-14 year old girls having the least amount of PA participation. Almost half of the total participants met the recommended guidelines for PA; again more boys than girls met the guidelines irrespective of age.

4.2 PA and Sedentary Behaviour - Accelerometer Data

This section will present the analysis of both PA and sedentary behaviour (SB) from data gathered using accelerometers. PA will be examined in terms of overall PA, intensity, steps per day, MVPA and meeting PA guidelines. Sedentary behaviour will be analysed as overall SB, and also broken down into sedentary bouts and breaks in SB.

4.2.1 Description of Participants

All participants were full time secondary school students. Out of the 77 that participated, 28 did not have a set of at least 4 days of valid recorded data. The first day of the 7-day wearing time protocol was excluded; therefore the maximum number of data for each participant was 6 days; *Table 8.*

Table 8

Compliance with wearing the accelerometer

	n	**%**
Total Sample	77	100
No ActivPAL Data	7	9.1
<4 Days Data	14	18.2
No Weekend Day Data	7	9.1
≥ 4 Days Data (Including at least 1 weekend day)	49	63.6

In total, there were 49 adolescents (41% girls, 59% boys) with valid accelerometer data. The mean (±SD) age was 14.49 ± 1.12 years (range 13-16 years). Second year students made up 53.1% of the participants, with the remaining 46.9% in fourth (transition) year in school. Participant characteristics are presented in *Table 9.*

Table 9

Participant Characteristics

	% (n) Girls	% (n) Boys
Total	20	29
Age		
- 13	14.3 (7)	10.2 (5)
- 14	8.2 (4)	18.4 (9)
- 15	10.2 (5)	14.30 (7)
- 16	18.2 (4)	16.3 (8)
Year		
- 2nd	22.5 (11)	30.6 (15)
- 4th	18.4 (9)	28.6 (14)

4.2.2 Overall PA Patterns

The ActivPAL data was normally distributed, therefore mean and standard deviation values are used to present the results in this section. The overall total mean (±SD) PA was 117.67 ± 35.32 minutes per day. There was no significant difference between boys and girls (118.41± 32.03 and 117.21 ± 40.49 mins/day respectively, p =.901). There was also no significant difference in mean PA between the age groups (13/14 year olds 118.27 ± 32.26 and 15-16 year olds 117.55 ± 38.96, p=0.944). *Figure 7* shows the difference in mean PA in mins/day between gender/age combined, with no significance found (p=.187 for 13-14 year old boys and girls and p=.393 between 15-16 year old boys and girls). Older girls do almost 20 mins/day more total PA than their younger counterparts (p=.302), while younger boys do approximately 15 minutes more than the older group (p=.229).

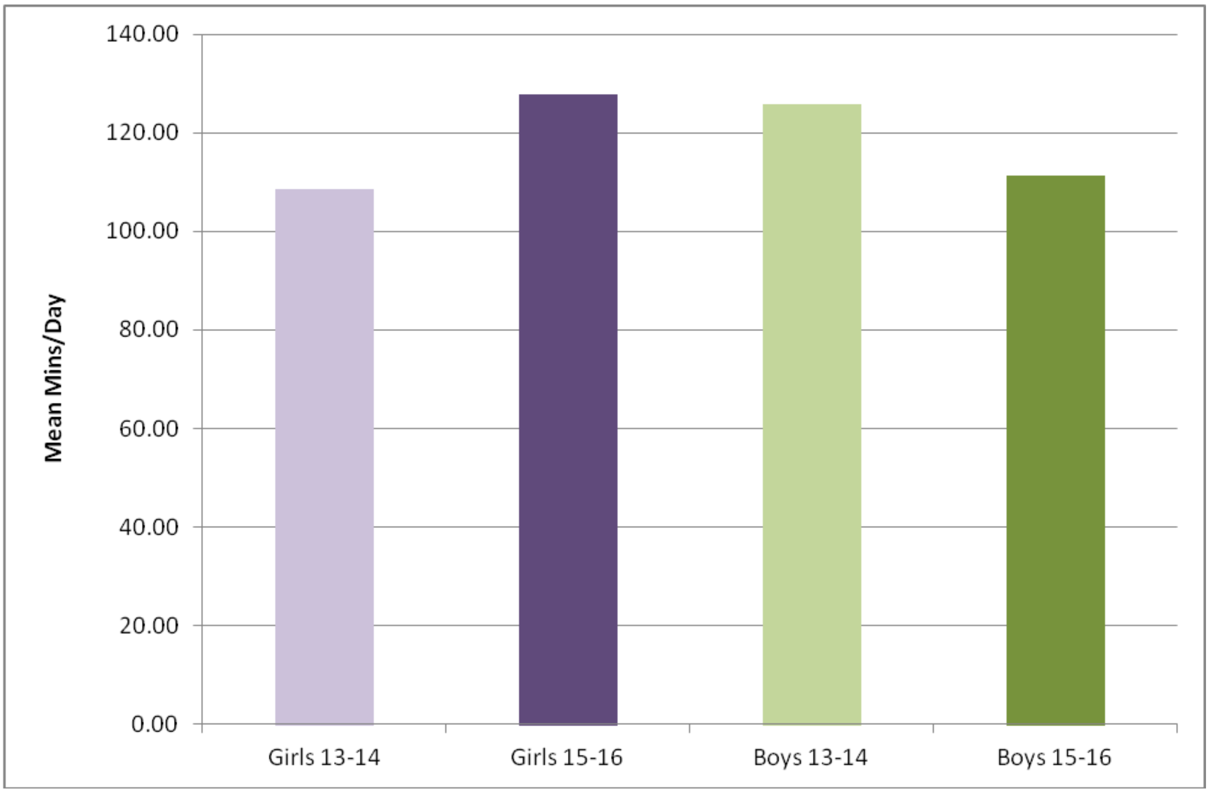

Figure 7

Gender/age comparison of total mean PA (mins/day)

4.2.3 Steps per Day

The mean average number of steps per day was 10474.66 ±5526.6. There was no significant difference between boys and girls (10848.33 ± 6480.2 and 9932.84 ± 3841.3, p=0.574). There was also no significant difference in steps when analysed across age groups or across gender/age combined; *Figure 8.*

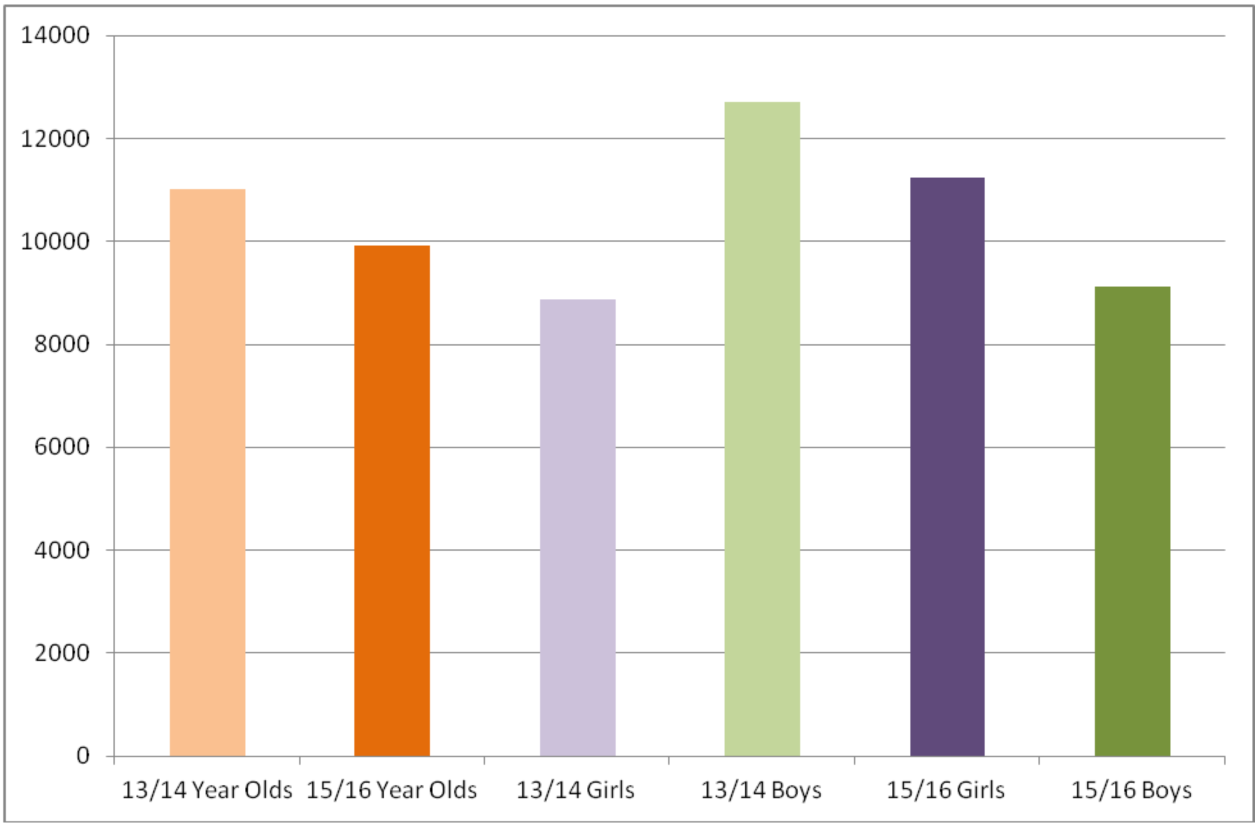

Figure 8

Age and gender/age comparisons of the mean number of steps per day

4.2.4 PA Intensity

Overall, participants were found to engage in a mean ± SD of 82.59 ± 25.60 minutes of light PA per day. There was no significant difference between boys and girls (84.7 ± 25.1 and 79.53 ± 26.66 minutes respectively, p=0.493) nor was there a significant difference between the age groups. The overall mean MVPA daily was 35.33± 19.93 minutes. *Table 10* outlines the mean and standard deviation for PA intensity by gender, age, and gender/age combined. The 13/14 year old boys participated in 8.5 minutes more MVPA daily than their female counterparts, while in the 15/16 year old category, girls took part in18 minutes more MVPA daily than boys; however, neither of these differences were significant.

Table 10

Mean time spent in PA of different intensities

	Mean Light PA (SD)	**p**	**Mean MVPA (SD)**	**p**
Girls	79.53 (26.66)	0.493	37.68 (24.59)	0.498
Boys	84.70 (25.11)		33.70 (16.25)	
13/14 year olds	85.2 (25.78)	0.473	33.07 (13.66)	0.431
15/16 year olds	79.88 (25.67)		37.68 (24.96)	
13/14 year old Girls	80.24 (23.48)	0.405	28.31 (10.55)	0.125
13/14 year old Boys	89.1 (27.67)		36.81 (14.99)	
15/16 year old Girls	78.67 (31.58)	0.875	49.13 (32.08)	0.142
15/16 year old Boys	80.6 (22.62)		30.8 (17.34)	

4.2.5 Meeting the PA Guidelines

Participants were categorised as either meeting or not meeting the PA guidelines based on the Department of Health and Children (2009) recommendations that children and young people need at least 60 minutes of MVPA daily. Ten percent of participants accumulated at least 60 minutes per day of MVPA, and thus were sufficiently active. *Table 11* shows that a higher proportion of girls met the PA guidelines than boys (p=.357). In two of the sub group categories (13-14 year old girls and 15-16 year old boys) none of the participants met the recommendations for daily PA but there was a significant difference between 15-16 year old boys and girls; 33% of girls met the PA guidelines compared to none of the boys in this age group (p = .017).

Table 11

Percentage of students meeting the daily MVPA guidelines

	% >60 mins/day (n)	p
Girls	15.0 (3)	0.357
Boys	6.9 (2)	
13-14 year olds	8.0 (2)	0.603
15-16 year olds	12.5 (3)	
13-14 year old girls	0 (0)	0.191
13-14 year old boys	14.3 (2)	
15-16 year old girls	33.3 (3)	0.017*
15-16 year old boys	0 (0)	

* $p < 0.05$

4.2.6 Sedentary Behaviour (SB)

The average time spent in SB per day was 9.63 hours ± 1.22. Boys average daily sedentary time was 9.72 ± 1.09 hours while for girls it was 9.50 ± 1.42 hours. There was no significant difference in time engaged in SB between boys and girls, age groups or between gender/age combined (*Figure 9).*

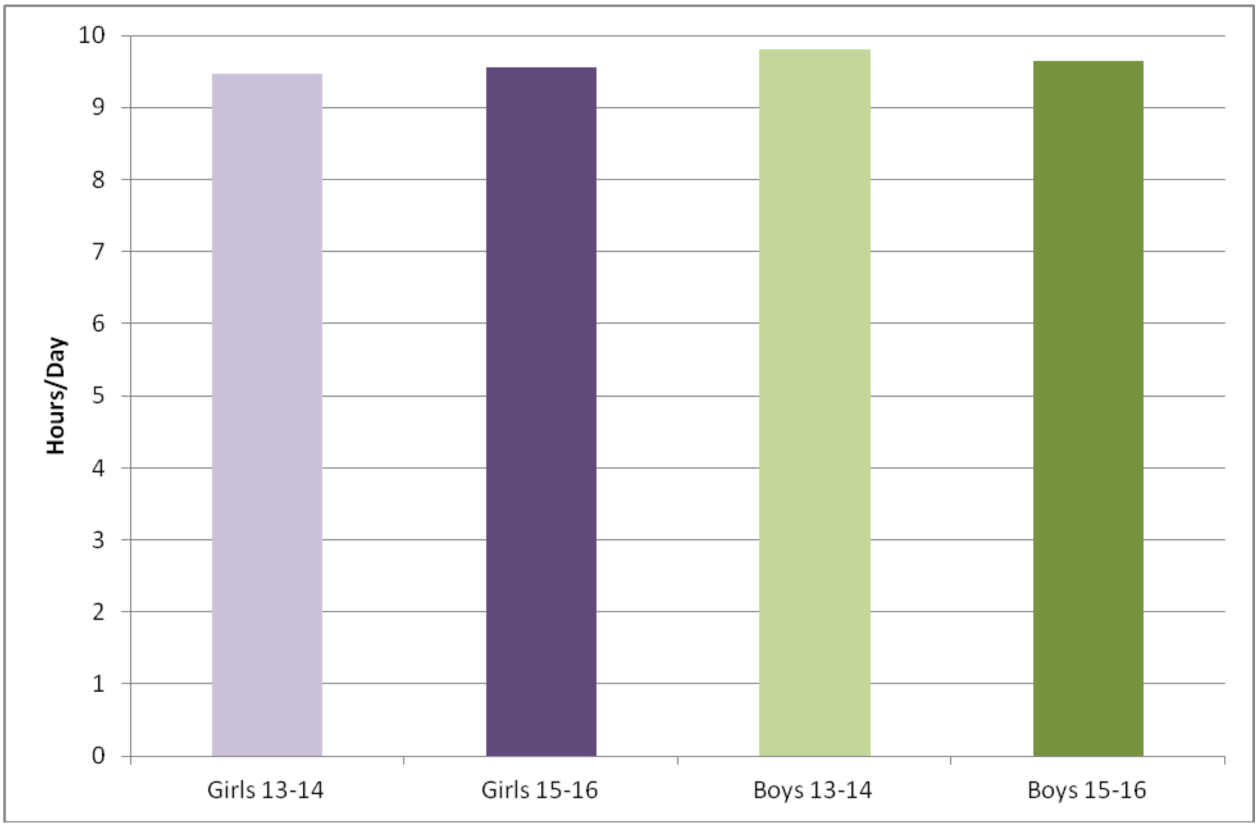

Figure 9

Gender/age comparison of SB (hours/day)

The correlation between sedentary time and total PA daily was examined. Overall, the correlation was -.473 (p=.001) indicating that those who engaged in more PA had lower levels of SB. For girls, the correlation between sedentary time and total PA daily was -.573 (p=.008) while for boys it was -.370 (p=.048).

4.2.7 Sedentary Bouts

The mean total number of sedentary bouts per day was 66.85 ± 14.24. *Figure 10* shows a breakdown by gender and age of the average total daily sedentary bouts. There was a significant difference between girls and boys (71.79±13.35 and 63.46±14.04 respectively; p=.043), but not between age groups (13-14 year olds 70.53±16.05 and 15-16 year olds 63.02±11.15, p=.064).

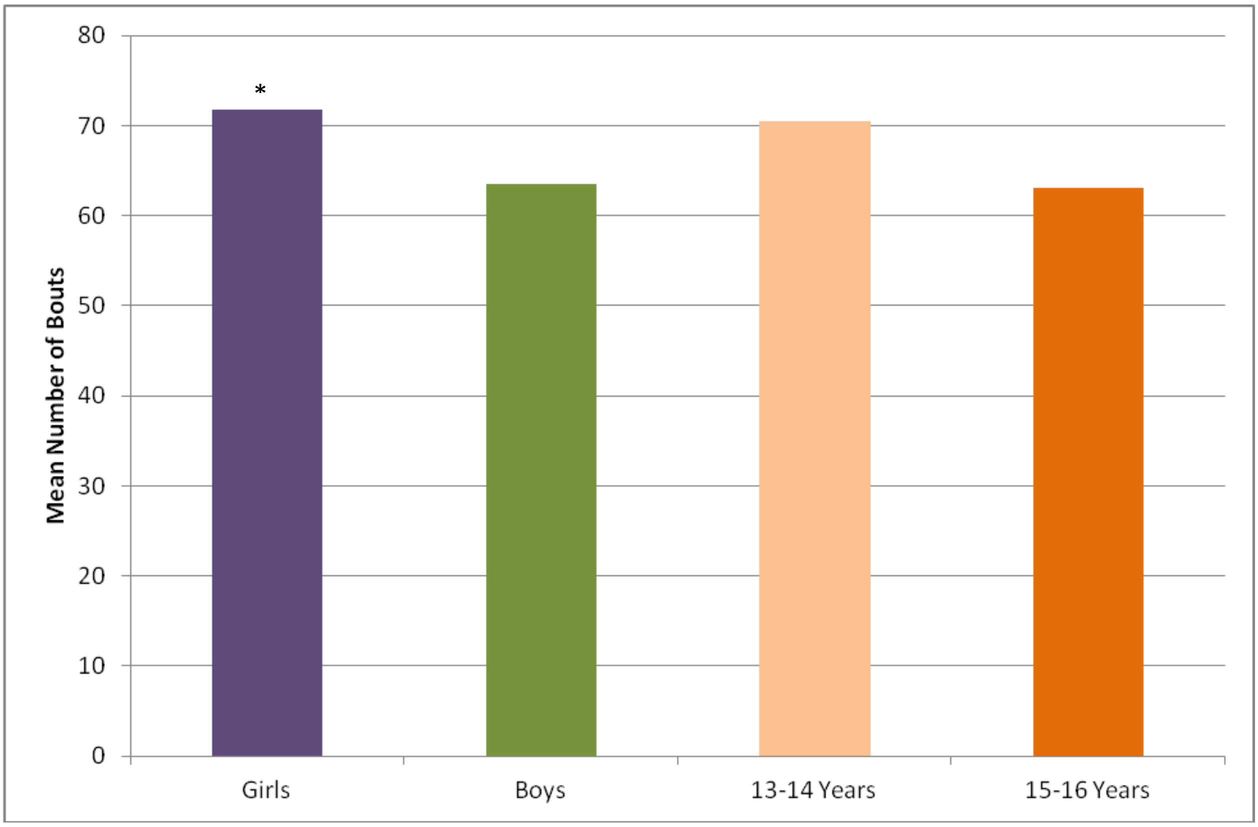

Figure 10

Total mean number of sedentary bouts per day by gender and age groups. * p<.05

Bouts of SB were also broken down into the number of bouts, and cumulative time spent in categories of different duration (*Table 12*). Most sedentary bouts were between 0-20 minutes in duration. As the length of time of the bouts increased, the number of bouts decreased. Girls had significantly more bouts between 0-20 minutes than boys (56.01±15.0, 46.27±15.72 respectively; p<.05) while boys had an average of 5.15±1.4 bouts greater than 30 minutes, with girls averaging 4.29±1.31 in the same time category (p<.05). When comparing the age categories, the only significant difference was in the number of bouts greater than 60 mintues, with the 15-16 year olds having a mean of 1.35±0.69 bouts compared to 0.96±0.46 for the 13-14 year olds (p<.05).

Table 12

Number and mean time of bouts overall and by gender and age categories

	Overall Mean (SD)	Girls Mean (SD)	Boys Mean (SD)	p	13- 14 yrs Mean (SD)	15-16 yrs Mean (SD)	p
No Bouts 0-20mins	50.24 (16.01)	56.01 (15.00)	46.27 (15.72)	0.035 *	53.94 (17.98)	46.39 (12.96)	0.098
Time 0-20 mins	220.05 (48.06)	228.69 (47.84)	215.46 (48.29)	0.349	231.13 (51.75)	210.16 (42.32)	0.128
No Bouts >20	8.2 (2.01)	8.04 (2.15)	8.39 (1.93)	0.557	8.44 (1.98)	8.05 (2.06)	0.497
Time >20 mins	373.31 (91.14)	360.64 (93.04)	380.35 (90.57)	0.463	367.80 (92.01)	377.01 (91.97)	0.728
No Bouts >30	4.8 (1.418)	4.29 (1.31)	5.15 (1.40)	0.036*	4.85 (1.50)	4.73 (1.34)	0.728
Time >30 mins	287.62 (91.44)	267.02 (91.41)	301.83 (90.28)	0.193	280.42 (94.47)	295.13 (89.58)	0.579
No Bouts >40	2.41 (0.91)	2.30 (0.88)	2.47 (0.94)	0.599	2.33 (0.89)	2.50 (0.94)	0.498
Time >40 mins	204.39 (89.29)	199.47 (93.11)	207.79 (88.07)	0.752	191.61 (92.33)	217.71 (85.91)	0.311
No Bouts >60	1.15 (0.61)	1.11 (0.53)	1.18 (0.67)	0.703	0.96 (0.46)	1.35 (0.69)	0.027*
Time >60 mins	130.73 (79.34)	133.38 (86.7)	128.9 (75.38)	0.849	112.06 (68.54)	150.18 (86.46)	0.093

* p<.05

4.2.8 Breaks in Sedentary Time

The mean number of breaks in sedentary time per day was 58.66 ±15.75. Girls had significantly more breaks than boys (64.15 ± 14.53 and 54.85 ±15.67, p = .041). There was no significant difference between the age groups (p=0.05); *Figure 11*.

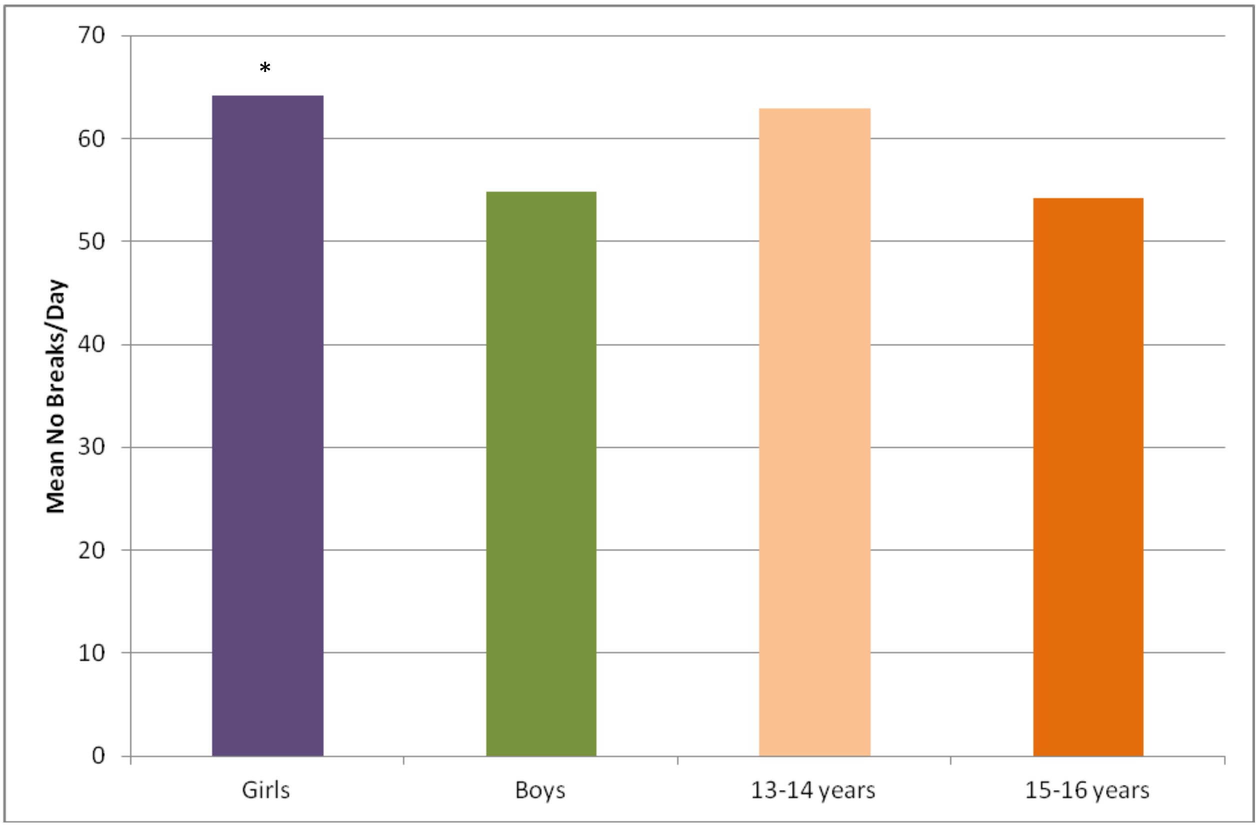

Figure 11

Gender/Age comparison of Breaks in Sedentary Behaviour. *p<.05

The average duration of the break time (minutes) between bouts of sedentary time was 5.37 ± 1.54 minutes. The mean maximum break time taken was 54.81 ±19.49 minutes while the minimum mean break time was 0.13 ± 0.05 minutes. The 15-16 year old mean break time was significantly longer than their younger counterparts (5.95 ± 1.62 mins, 4.81 ± 1.24 mins respectively, p = .008). *Table 13* displays the overall average break time, and mean maximum and minimum break times by gender, age and gender/age combined.

Table 13

Overall mean (SD) average, maximum and minimum break times

	Average Break (SD)	**p**	**Max Break (SD)**	**p**	**Min Break (SD)**	**p**
Girls	5.16(1.77)	0.426	50.67 (14.48)	0.221	0.13 (0.05)	0.911
Boys	5.52 (1.37)		57.67 (22.09)		0.13 (0.05)	
13/14 year olds	4.81 (1.24)	0.008*	52.21 (20.92)	0.345	0.12 (0.05)	0.224
15/16 year olds	5.95 (1.62)		57.52 (17.92)		0.14 (0.05)	
13/14 year old Girls	4.33 (0.93)	0.084	44.64 (15.16)	0.344	0.12 (0.04)	0.726
13/14 year old Boys	5.19 (1.35)		55.8 (24.5)		0.12 (0.05)	
15/16 year old Girls	6.17 (2.07)	0.622	54.38 (13.51)	0.518	0.14 (0.06)	0.776
15/16 year old Boys	5.82 (1.36)		59.41 (20.32)		0.14 (0.05)	

* p<.01

The correlation between the total number of breaks and total PA time and MVPA time was examined *(Table 14).* There was a moderate correlation found for total PA overall, for boys and for 13-14 year olds. However, no relationship was found for total number of breaks and MVPA.

Table 14

Pearson Correlation between the total number of breaks and total PA and MVPA

	Overall R (p)	Girls R (p)	Boys R (p)	13/14 years R (p)	15/16 years R (p)
Total PA	.310 (.03)*	.125 (.599)	.499 (.006)**	.413 (.040)*	.232 (.276)
MVPA	-.015 (.920)	-.156 (.512)	.056 (.774)	.034 (.873)	.011 (.96)

*p<.05; **p<.01

4.2.9 Summary of ActivPAL Results

Overall time spent in PA and number of steps per day were similar across gender, age and gender/age combined. Girls participated more MVPA daily than boys, although this was not a significant difference. Only 10.2% of all particpants met the daily MVPA guidelines of 60 minutes per day. None of the 13-14 year old girls or 15-16 year old boys met these guidelines. Time spent in SB was similar between groups. Girls engaged in more sedentary bouts overall than boys, but had more breaks in SB. A moderate correlation was found between the number of breaks in SB and total time spent in PA for the whole group, boys and the 13-14 year old age cohort.

4.3 Agreement between Measurement Methods

This section will examine data gathered from both the IPAQ-A and ActivPAL in terms of the level agreement between the two methods of measurement. Only the questionnaires filled out by those who also wore the ActivPAL were used for this analysis. The first part will consider overall PA while the second will look at MVPA.

4.3.1 Total PA

As can be seen in *Table 15*, time spent in total PA according to the questionnaire was higher for the total group, boys, and the 15-16 year olds. There was no difference in the 13-14 year old group and total IPAQ-A PA for girls was 20 minutes lower than ActivPAL PA. Spearman correlation coefficient values ranged between -.061 to .327 overall and for all sub-groups, indicating weak correlations between the instruments. Significant differences between the measurement instruments were found for boys and the 15-16 year age cohort.

Table 15

Mean and percent difference between measurement of total PA by IPAQ-A and ActivPAL

	IPAQ-A PA Mean Minutes (SD)	**ActivPAL PA Mean Minutes (SD)**	**Mean Difference in Minutes (SD)**	**% Difference**	**p**
Overall	135.27 (76.48)	118.24 (35.93)	16.60 (78.33)	14.0	.162
Girls	99.18 (66.93)	119.50 (42.08)	-20.32 (76.93)	-17.0	.278
Boys	159.32 (73.94)	117.43 (32.17)	41.21 (70.29)	35.1	.005*
13-14 Years	119.00 (74.22)	119.48 (32.38)	-0.48 (79.35)	-0.4	.977
15-16 Years	153.86 (76.50)	116.89 (40.18)	36.12 (74.21)	30.9	.037*

* $p < 0.05$

The percent difference between IPAQ-A and ActivPAL in measuring total PA is shown in *Figure 12* below. Girls were the only group to underestimate their total PA in the self report tool in comparison to the objective measurement. There was only a -0.4% difference between the objective and subjective total PA for the 13-14 year old category.

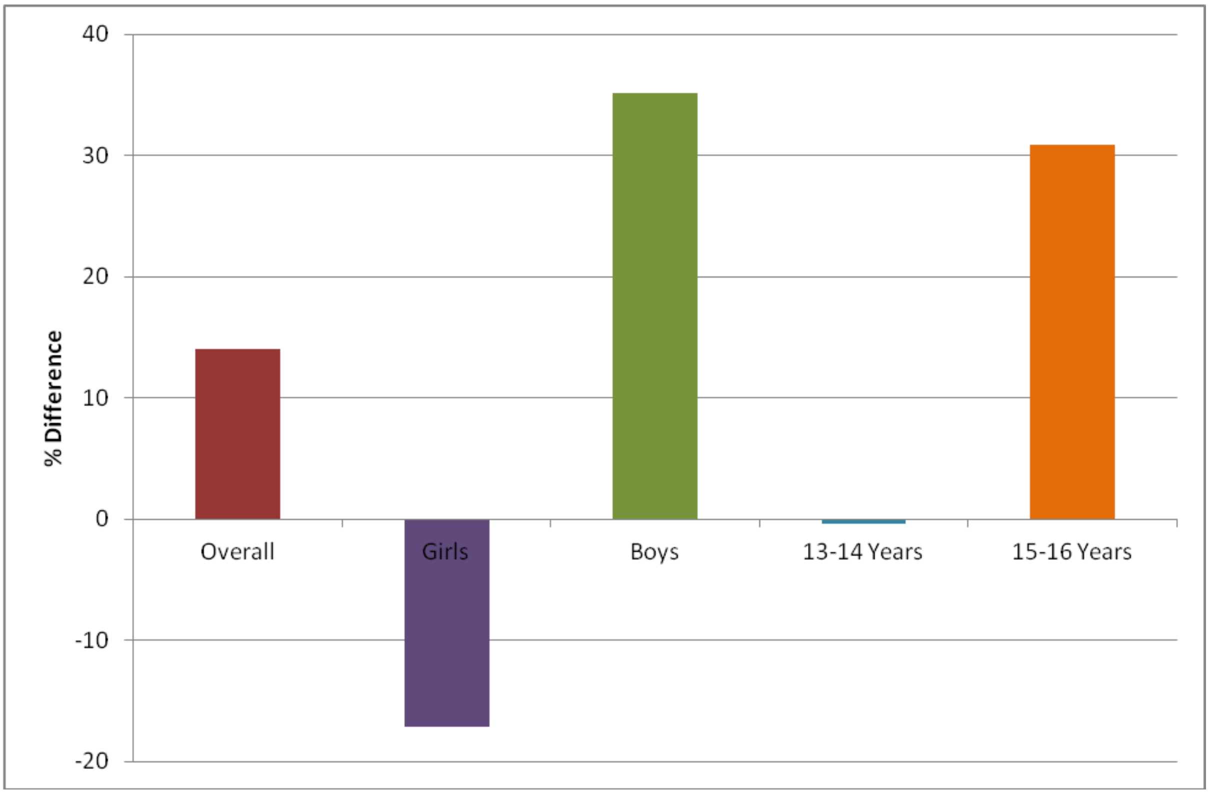

Figure 12

Percent difference in total PA as measured by IPAQ-A and ActivPAL; positive figures represent over-estimation on the IPAQ-A while negative figures represent under-estimation

The Bland Altman method was used to examine the level of agreement between the IPAQ-A and ActivPAL in recording total time spent in PA. *Figure 13* shows the scatter plot of the difference and mean total PA of the two measurement tools and indicates considerable variation in the individual difference between the questionnaire and accelerometer estimates. For each individual, the difference was calculated by subtracting the ActivPAL score from the IPAQ-A score. There is a mean difference of 16.6±78.33 mins/day; with a 95% lower confidence level of -6.93 and 95% upper confidence level of 40.13 mins/day. This indicates that participants over reported PA by approximately 16 minutes per day compared to that recorded by the ActivPAL.

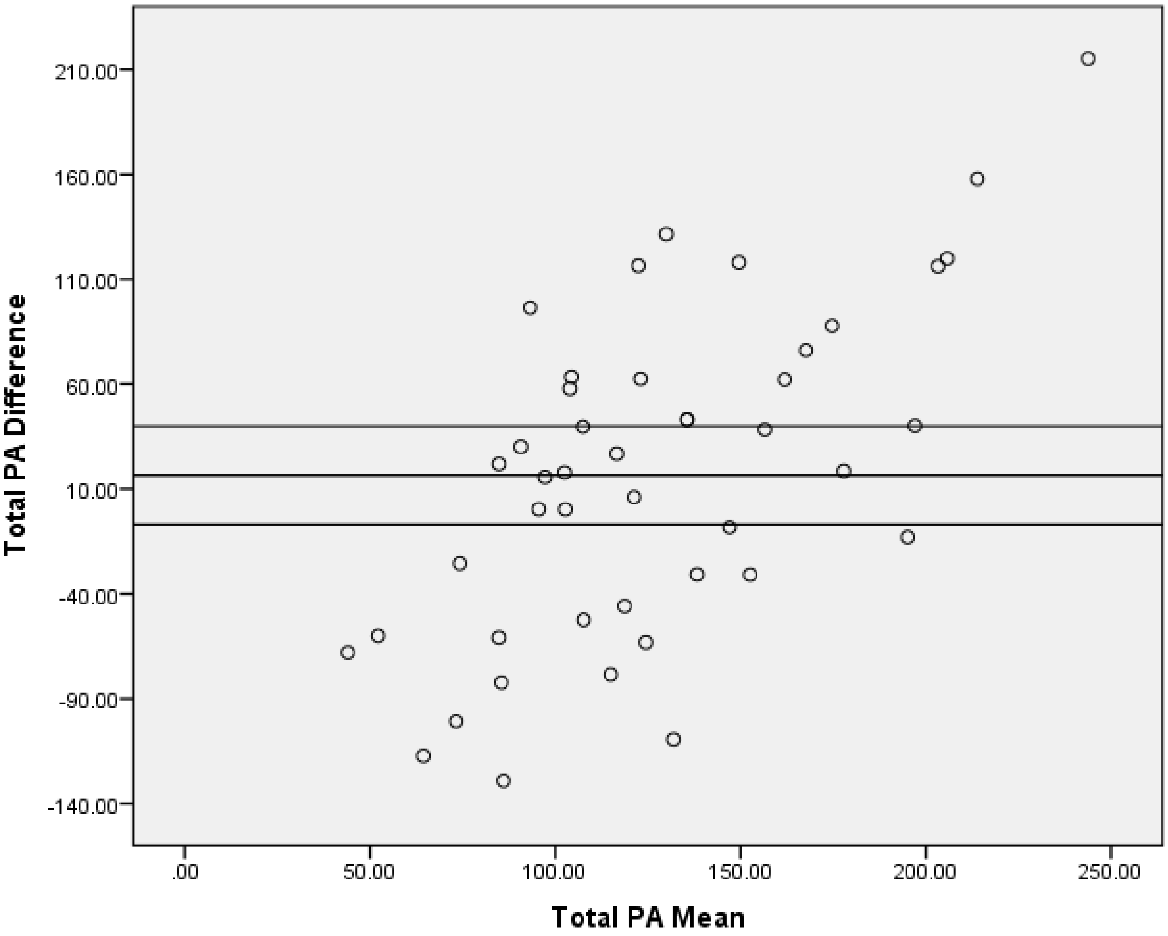

Figure 13

Bland Altman plot of total PA measured by IPAQ-A and ActivPAL

4.3.2 MVPA Data

Table 16 displays the time spent in MVPA derived from the IPAQ-A and ActivPAL, the mean and percent difference between them, and results of a paired sample t-test. MVPA from the IPAQ-A was always higher than that recorded by accelerometer and differed significantly ($p < 0.05$) overall and for all subgroups except the girls. *Figure 14* shows the percent difference between the measurement tools. The Spearman rank correlation coefficiants (Rs) between the IPAQ-A and ActivPAL scores ranged between -.013 to .302 indicating little to low correlation between the two instruments.

Table 16

Mean difference, percent difference, correlation and significance values between measurement of MVPA by IPAQ-A and ActivPAL.

	IPAQ-A MVPA Mean (SD)	ActivPAL MVPA Mean (SD)	Mean Difference (SD)	% Difference	p
Overall	74.30 (48.62)	36.25 (20.21)	37.28 (52.73)	102.8	.000*
Girls	60.21 (50.01)	39.7 (25.10)	20.51 (60.10)	51.7	.166
Boys	83.69 (46.22)	34.03 (16.45)	48.47 (44.93)	142.4	.000*
13-14 Years	76.41 (56.34)	33.45 (13.82)	42.96 (58.17)	128.4	.001*
15-16 Years	71.88 (39.23)	39.30 (25.43)	30.79 (46.27)	78.3	.006*

* $p < 0.05$

Figure 14 below graphs the percentage difference between the IPAQ-A and ActivPAL in measuring MVPA. Girls had the lowest percent difference. There was a large variation between the age groups also with the younger adolescents over reporting by 50% on the IPAQ-A when compared to ActivPAL.

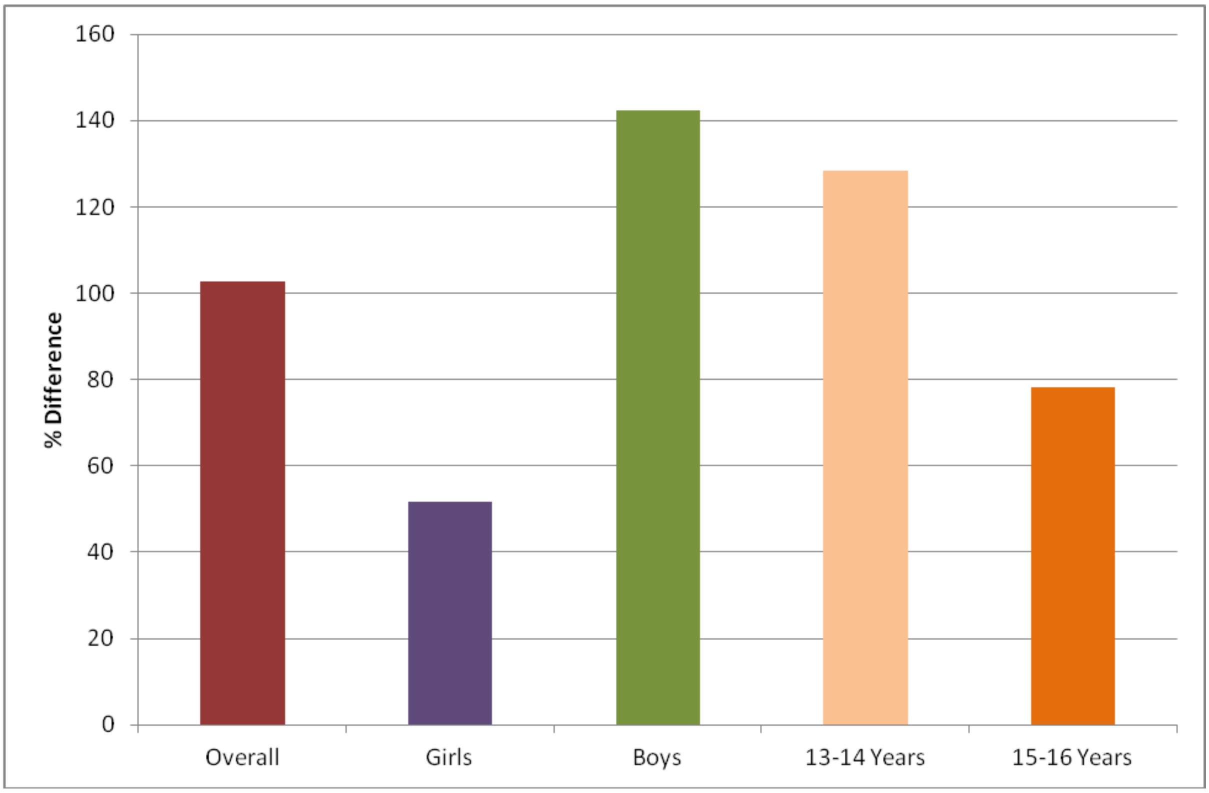

Figure 14

Percent difference between MVPA as measured by IPAQ-A and ActivPAL

The Bland Altman method was used to examine the level of agreement between the IPAQ-A and ActivPAL in recording MVPA. *Figure 15* shows the scatter plot of the difference and mean MVPA of the two measurement tools. The Bland-Altman plot for MVPA in minutes per day from the accelerometer and questionnaire demonstrated a mean difference of 37.28±52.73 mins/day; with 95% lower confidence level of 21.44 and 95% upper confidence level of 53.12, indicating over estimation by self-report. Results show considerable variation in the individual differences between the questionnaire and accelerometer estimates of MVPA.

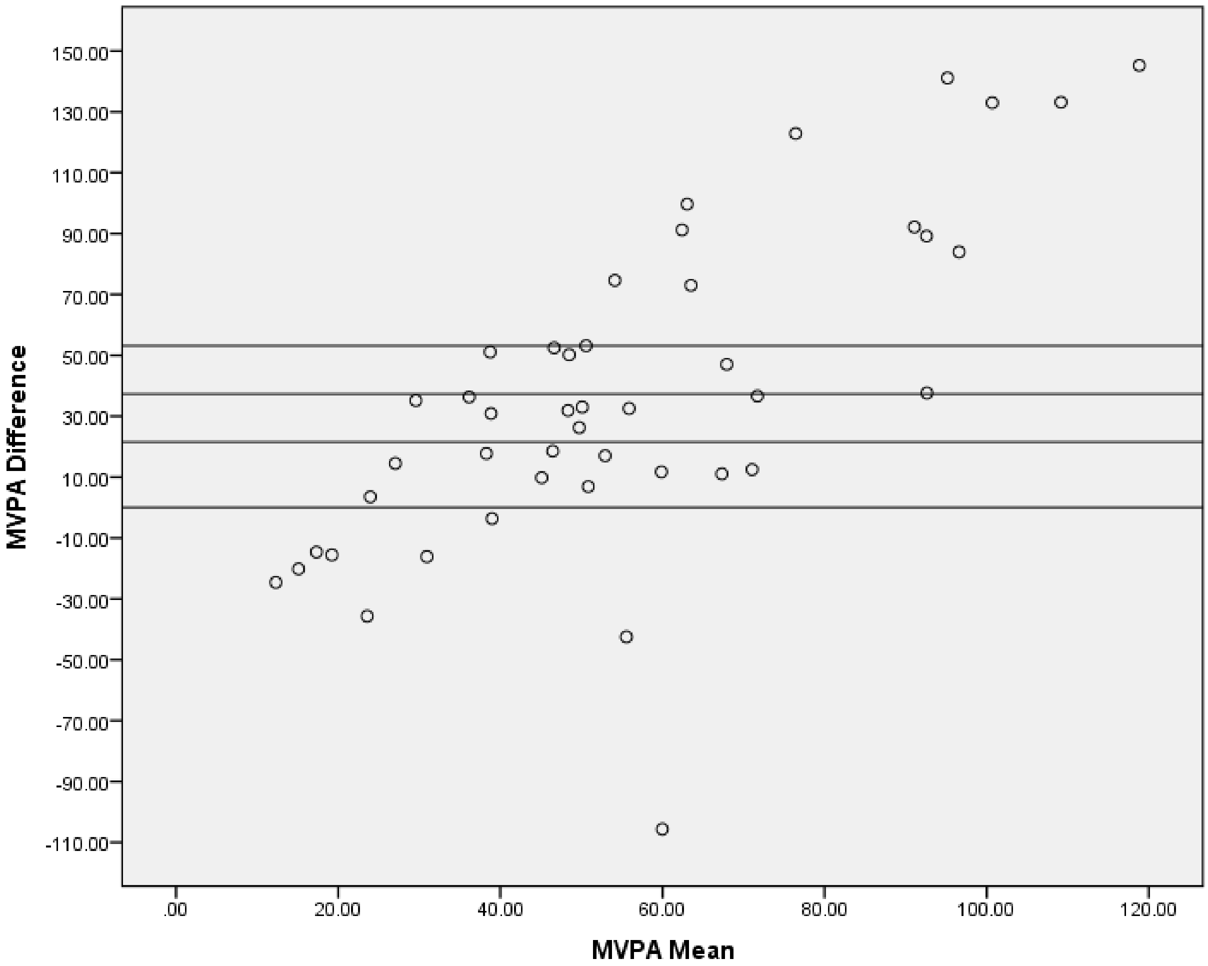

Figure 15

Bland Altman plot of MVPA measured by IPAQ-A and ActivPAL

4.3.3 Summary of Agreement between Measurement Methods

Total PA time measured by the IPAQ-A was higher for the whole group, boys and the 15-16 year old age category compared to the ActivPAL. For the 13-14 year olds, the total PA time recorded by the two methods was almost the same. Girls, however, underestimated their total PA in the IPAQ-A by nearly 20 minutes compared to the ActivPAL. MVPA recorded by IPAQ-A was higher for all groups. Bland Altman plots for both total PA and MVPA revealed considerable variation between the two measurement methods.

4.4 Active Travel

This section will look at data gathered from the IPAQ-A in relation to Active Travel (AT). The first part will focus on overall AT patterns. This will be followed by domains of AT, school-based AT, AT and MVPA and attitudes to AT. Finally perception of distance travelled to school will be examined.

4.4.1 Overall Active Travel PA Patterns

AT was defined as either walking or cycling to get from place to place. As previously metioned in section 4.1.4. participants reported a median of 17.14 (IQR 63.21) mins/day of AT. The breakdown of AT by sub-groups is displayed in Table 17. There is a significant difference in total active travel time daily between boys and girls, age groups and the younger adolescents. *Figure 4, (*in section 4.1.4) graphs the gender, age and gender/age comparisons of total AT daily.

Table 17

Total Active Travel Time Daily by Gender, Age and Gender/Age Combined (median mins/day)

	n	**Median (IQR)**	**p**
Girls	199	14.29 (50.00)	.001**
Boys	95	32.14 (111.43)	
13-14 Years	173	10.71 (60.71)	.014*
15-16 Years	121	25.71 (71.43)	
13-14 Girls	117	8.57 (35.57)	.000**
13-14 Boys	56	34.29 (104.82)	
15-16 Girls	82	23.57 (48.75)	.421
15-16 Boys	39	30.00 (111.43)	

**p<0.01* p < 0.05

4.4.2 Total Active Travel Time Daily and its relationship to PA

Using Spearmans Rho correlations, the relationship between active travel time daily and time spent in PA, MVPA, moderate PA and vigorous PA from the IPAQ-A were examined. As can be seen from *Table 18*, almost all of the correlations were signficant, indicating a postive relationship between AT and physical activity overall and at different intensities.

Table 18

Spearmans Rho correlations (Rs) and their corresponding significance values for Total PA, MVPA, Moderate PA, Vigorous PA and their relationship to Total Active Travel Time Daily

	Total PA Rs	**p**	**MVPA Rs**	**p**	**Moderate PA Rs**	**p**	**Vigorous PA Rs**	**p**
Overall	.779	.000**	.319	.000**	.366	.000**	.153	.013*
Girls	.766	.000**	.329	.000**	.325	.000**	.180	.015*
Boys	.790	.000**	.273	.007**	.406	.000**	.103	.351
13/14 year olds	.743	.000**	.366	.000**	.406	.000**	.180	.024*
15/16 year olds	.821	.000**	.237	.000**	.284	.002**	.134	.163

**p<0.01* p < 0.05

4.4.3 Domains of AT

4.4.3.1 Walking for Transport

The average time for all participants spent walking for transport was 17.14 (IQR 59.64) mins/day. Boys and the 15 - 16 year old age group reported significantly more time walking for transport than girls and the 13-14 year olds (p = .008 and p = .007 respectively). The 13 - 14 year old girls spent significantly less (p = .005) time walking for transport than 13- 14 year old boys; *Table 19.*

4.4.3.2 Cycling for Transport

The average time spent cycling for transport was 21.43 (IQR 51.43) mins/day. Girls spent almost 12.5 minutes less cycling for transport than boys per day (p =.000). There was no significant difference between the age groups, however, both male 13-14 year olds and male 15-16 year olds reported significanly more time cycling for transport than their female counterparts (p = .001 and p = .003 respectively).

Table 19

Gender and Age comparison of Walking and Cycling for Transport (median mins/day)

	n	Walking for Transport (IQR)	p	n	Cycling for Transport (IQR)	p
Overall	268	17.14 (59.64)		278	21.43 (51.43)	
Boys	85	22.86 (94.64)	.008*	93	23.21 (46.43)	.000**
Girls	183	14.29 (42.86)		185	10.72 (32.32)	
13-14 y	154	8.57 (51.79)	.007*	161	17.14 (37.86)	.319
15-16 y	114	24.29 (52.86)		117	15.0 (40.89)	
Girls 13-14	103	8.57 (28.57)	.005*	107	11.43 (26.97)	.001*
Boys 13-14	51	19.29 (85.71)		54	19.29 (36.79)	
Girls 15-16	80	20.71 (43.93)	.295	78	7.86 (16.6)	.003*
Boys 15-16	34	30.00 (100.0)		39	17.14 (44.29)	

*p<.05; **p<.001

Over three quarters (80%, n = 287) of respondents either owned or had access to a bicycle. Boys had slightly higher bike ownershitp (81%, n=112) than girls (78%, n=175), but the difference was not significant. Similarly, there was no signifcant difference betwen the age groups, with 78% of 13-14 year olds and 82% of 15-16 year olds with bike access.

4.4.4 School Based AT

4.4.4.1 Usual Travel to School

Most students travel to school by car (63.9%), followed by walking (18.5%) and bus (15.9%). Of the 352 participants, only 5 cycled to school (3 boys, 2 girls). None of the 15-16 year old girls cycled to school (n = 88). The train was the least frequently reported mode of transport (0.3%). Travel to school was categorised as Active Travel (walk/cycle) and Motorised Travel (car/train/bus). Overall 19.9% of students actively travelled to school (n=70). *Table 20* shows a breakdown of how students travelled to school.

Table 20

Mode of transport to school by gender and age and gender/age combined

	Active Travel % (n)	**Motor Travel % (n)**	**p**
Girls	15.5 (34)	84.5 (187)	.006*
Boys	27.5 (36)	72.5 (95)	
13- 14	25.6 (56)	74.4 (165)	.001*
15-16	10.8 (14)	89.2 (116)	
Girls 13-14	20.6 (27)	79.4 (104)	.034*
Boys 13-14	33.0 (29)	67.0 (59)	
Girls 15-16	8.0 (7)	92.0 (81)	.134
Boys 15-16	16.7 (7)	83.3 (35)	

*p<.05

4.4.4.2 Preferred Travel to School

Most students preferred method of travel to school would be by car (55.8%), followed by walking (18%) and bus (14.9%) with the least popular option by bicycle (11.3%).

4.4.4.3 Distance Travelled to School

Table 21 shows the average distance and time to school by mode of transport. The overall average distance to school was 9.25km (IQR = 11.4) and the time taken to travel to school was 15.0 mins (IQR = 19.0). Distance for those who actively travel to school was considerably lower than those who used motorised transport; whereas time taken was the almost the same.

Table 21

Average (median) distance (kilometers)and time(mins) travelled to school by mode of transport

	Frequency % (n)	**Distance (IQR)**	**Distance Range**	**Time (IQR)**	**Time Range**
Active Travel	19.9 (70)	1.75 (1.1)	.7-2.9	13.8 (13.9)	2.0-45.0
Motorised Travel	80.1 (282)	9.3 (11.2)	.25-36.7	13.5 (20.5)	2.0-75.0

All of those who walked and cycled to school (n=66) lived within 3.0km of the school. *Figure 16* shows the mode of transport to school based on the distance travelled.

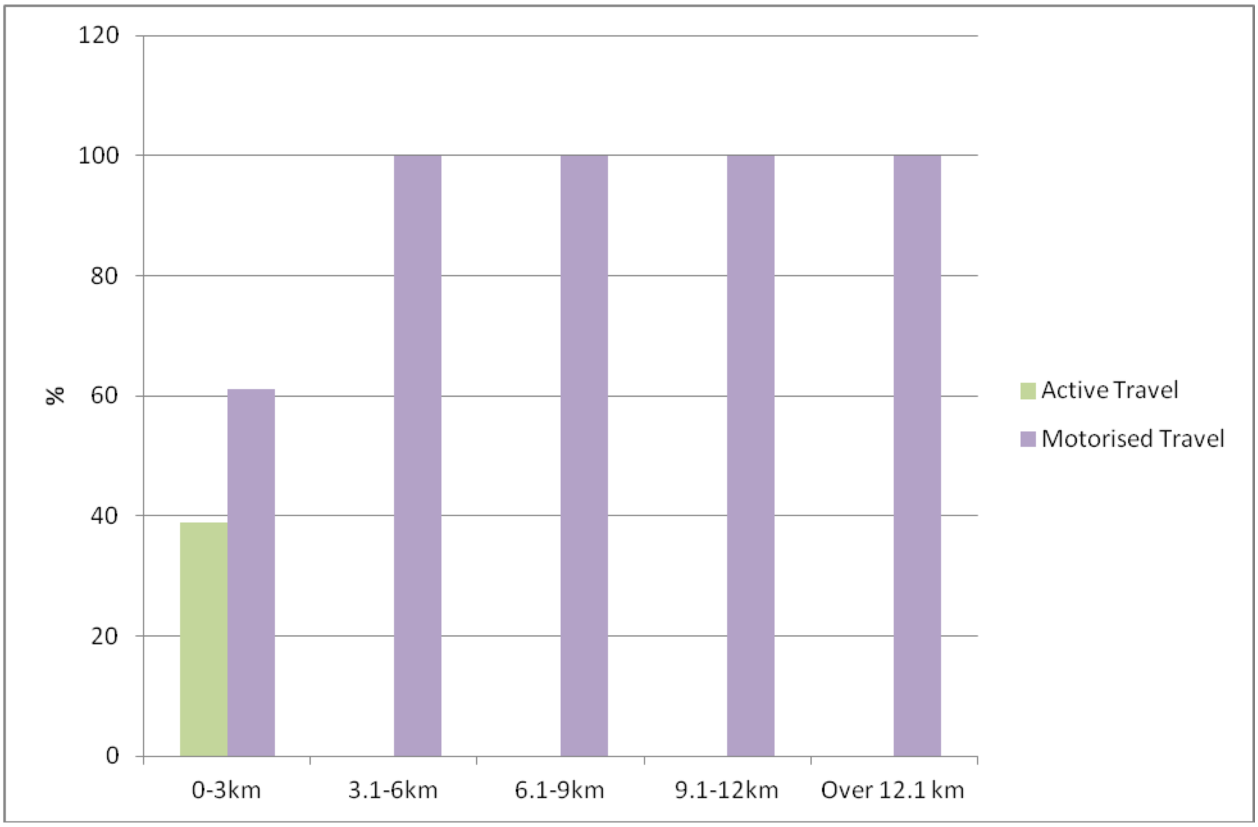

Figure 16

Mode of transport to school by the distance travelled

4.4.5 AT to School and PA

IPAQ-A data on PA levels were used in this section because there were only 6 participants who actively travelled to school with valid ActivPAL data. The overall total PA for those who actively travel to school was on average 50 minutes more daily than those who travelled to school by motorised means *(Table 22).* Similarly, gender and age subgroups showed greater total PA among those who AT, with almost 73 minutes more PA dailyfor the 15-16 year old age group (p=.012).

Table 22

Median total PA (mins/day) for those who actively travel versus those who do not

	n	Active Travel Total PA Median Mins/Day (IQR)	n	Non-Active Travel Total PA Median Mins/Day (IQR)	p
Overall	59	150.00 (154.96)	256	100.00 (105.00)	.001*
Girls	33	130.00 (170.29)	181	94.29 (104.29)	.084
Boys	26	168.57 (130.00)	75	127.14 (111.43)	.017*
13- 14	46	143.57 (154.96)	143	85.71 (97.86)	.005*
15-16	13	190.71 (133.57)	113	117.86 (96.07)	.012*

*p<.05

Differences in MVPA for those who atively travel verusus those who do not were a lot less than for total PA. The overall total MVPA for those who actively travel to school was just over 7 minutes more daily than those who travelled to school by motorised means *(Table 23).* There was no difference for boys as a sub-group. For girls and the age groups, MVPA for those who AT to school was slightly higher, but not significant.

Table 23

Median MVPA (mins/day) for those who actively travel versus those who do not

	n	Active Travel MVPA Median Mins/Day (IQR)	n	Non-Active Travel MVPA Median Mins/Day (IQR)	p
Overall	59	65.0 (98.57)	256	57.86 (67.14)	.309
Girls	33	60.71 (104.14)	181	55.71 (66.41)	.527
Boys	26	65.71 (85.96)	75	65.71 (63.57)	.829
13- 14	46	62.5 (105.11)	143	56.92 (69.82)	.585
15-16	13	65.71 (81.07)	113	60.0 (61.79)	.268

4.4.6 Barriers and Facilitators to Active Travel to School

4.4.6.1 Walking

Participants were asked about their perceptions of active travel and responses were compared across those did/did not actively travel to school *(Table 24)*. There was considerable variation across individual factors. For example, 86.6% of those who do not actively travel agree that the weather would affect their walking habits compared to 64.6% of those who do AT ($p<.001$). Practical issues, particularly how long it would take to travel to school, was also a bigger barrier for non active commuters ($p<.001$). In relation to socio-environmental factors, those who actively travel are more likely to agree that their friends also walk to school (76.6%). Both groups largely disagree that their friends would think they look stupid if they walk, however, the difference is still significant ($p=.006$). Parental/guardian influence is also different between the groups; with more parents of active travellers encouraging their children to walk ($p=.054$). Those who do not AT agree that their parents/guardians are happy to drive them places (80.5% compared to 44.4% of those who AT, $p<.001$). Students' perceptions of the physical environment vary significantly with active travellers agreeing that there is both a safe and direct route from their home to the school.

Table 24

Participants thoughts on AT (walking) - % Agree for all students and those who actively travel versus those who do not AT (n)

Statement	*All Students*	*Active Commuters*	*Non-Active Commuters*	*p*
Individual Factors - walking comfort				
I don't like to walk when the weather is bad	82.7 (336)	64.6 (65)	86.6 (262)	.000*
Individual Factors - other cognitive factors				
Walking to school would be too tiring	50.6 (336)	18.8 (64)	64.3 (263)	.000*
I couldn't be bothered walking to school	46.3 (341)	10.9 (64)	54.9 (268)	.000*
Individual Factors - practical issues				
I have lots of stuff to carry to school	72.4 (341)	66.7 (66)	73.7 (266)	.257
Walking to school would take too long	65.4 (338)	18.5 (65)	77.0 (265)	.000*
Walking to school would run my hair	26.7 (251)	18.0 (50)	27.2 (195)	.007*
Walking to school would ruin my make-up	23.6 (330)	18.3 (60)	23.8 (261)	.064
Social-environmental factors - peers				
Driving is the coolest way to get to school	31.6 (339)	20.3 (64)	33.5 (266)	.004*
My friends would think I looked stupid if I walked to school	9.2 (337)	4.8 (62)	10.9(266)	.001*
Other students would think I looked stupid if I walked to school	10.5 (342)	4.7 (64)	11.9 (269)	.006*
My friends walk to school	60.4 (338)	76.6 (64)	56.2 (265)	.007*
Social-environmental factors - parents				
My parents/guardians encourage me to walk to places	59.0 (339)	71.9 (64)	56.0 (266)	.054
My parents/guardians are happy to drive me to school	73.7 (339)	44.4 (63)	80.5 (267)	.000*
Physical-Environment factors				

There is a safe walking route from my house to school	41.2 (340)	82.3 (62)	31.5 (270)	.000*
There is a direct walking route from my house to school	35.7 (342)	64.6 (65)	28.7 (268)	.000*
I live too far away from the school to walk	52.9 (344)	12.3 (65)	63.0(270)	.000*

*p<.05

4.4.6.2 Cycling

Analysis of the agree-disagree statements in relation to cycling *(Table 25)* also reveal significant differences between those who actively travel and those who do not. Mode preference is significantly different with 84% of students who do not AT agreeing that driving is the easiest way to get to school versus 57.6% of those who actively travel ($p<.001$). There were no big differences when it comes to biking comfort, with both groups agreeing that they are confident in their cycling ability, hate wearing a cycle helmet and don't like to cycle in bad weather.

When it comes to practical issues, over 70% of both groups agree that they have lot of stuff to carry to school, while almost half agree that cycling to school would ruin their hair. However, there are significant differences between groups when it comes to length of time to cycle to school, 66.2% of non-active travellers agree that it would take too long as opposed to 11.9% ($p=.000$) of those who actively commute. Non-active travelllers also agree that the clothes they wear would make it difficult for cycling.

Social-environmental factors in relation to peers show that those who actively travel are more likely to agree that their friends also cycle to school. Both groups disagree that their friends or other students would think they look stupid if they cycle. Parental/guardian encouragement to cycle places are similar between groups, however, there is a significant difference between groups in relation to parents/guardians being happy to drive students to school; 80.4% of non-AT group, 37.9% of the AT group, $p<.001$). Half of those who actively travel worry about their bicycle being stolen in school with 41.5% of non-active travellers also agreeing with this statement.

Finally, there is a significant difference between groups in all statements pertaining to physical-environment factors. Only 16.2% of those who AT agree that cycling to school is not safe as opposed to 46.4% of those who travel by motorised means ($p<.001$). Over half (55.7%) of non-active travellers agree that they live too far from the school to cycle in contrast to only 3.1% of those who actively travel (p<.001).

Table 25

Participants thoughts on AT (cycling) - % Agree for all students and those who AT versus those who do not AT (n)

Statement	*All Students*	*Active Commuters*	*Non-Active Commuters*	*p*
Individual Factors - Mode Preference				
Driving is the easiest way to get to school	79.0 (343)	57.6 (66)	84.0 (269)	.000*
Individual Factors - biking comfort				
I am confident in by cycling ability	85.5 (352)	91.2 (68)	83.6 (274)	.120
I hate wearing a cycle helmet	77.5 (351)	78.8 (66)	76.8 (276)	.915
I don't like to cycle when the weather is bad	84.9 (352)	80.6 (67)	86.2 (275)	.251
Individual Factors - other cognitive factors				
Cycling to school would be too tiring	46.5 (355)	17.6 (68)	54.2 (277)	.000*
I couldn’t be bothered cycling to school	50.1 (351)	45.5 (66)	51.3 (275)	.126
Individual Factors - practical issues				
I have lots of stuff to carry to school	75.7 (354)	71.6 (67)	76.5 (277)	.332
Cycling to school would take too long	55.4 (352)	11.9 (67)	66.2 (275)	.000*
The clothes I wear make it hard to cycle	73.9 (352)	55.9 (68)	78.5 (275)	.000*
Cycling to school would run my hair	50.0	44.4 (54)	50.2 (201)	.343

	(262)			
Cycling to school would ruin my make-up	31.7 (338)	29.0 (62)	31.1 (267)	.136
Social-environmental factors - peers				
My friends would think I looked stupid if I cycled to school	27.0 (352)	32.8 (67)	25.8 (275)	.519
Other students would think I looked stupid if I cycled to school	30.8 (347)	29.9 (67)	31.4 (271)	.820
My friends cycle to school	20.6 (349)	34.3 (67)	15.8 (273)	.001*
Social-environmental factors - parents				
My parents/guardians encourage me to cycle to places	29.9 (344)	34.8 (66)	27.9 (269)	.480
My parents/guardians are happy to drive me to school	71.9 (345)	37.9 (66)	80.4 (270)	.000*
Social-environmental factors - community				
I worry about my bicycle being stolen in school	43.9 (344)	50.8 (65)	41.5 (270)	.170
Physical-Environment factors				
Cycling to school is not safe	40.4 (354)	16.2 (68)	46.4(276)	.000*
There is a safe cycling route from my house to school	25.3 (344)	46.2 (65)	19.3 (270)	.000*
There is a direct cycling route from my house to school	18.4 (343)	27.7 (65)	15.6 (269)	.003*
I live too far away from the school to cycle	45.2 (345)	3.1 65)	55.7 (271)	.000*

*p<.05

4.4.7 Perception of Distance Travelled

As shown in *Table 26*, 23% of all students who live within 3km of the school agree that they live too far to walk to school, while 15.2% agree that they live too far to cycle. For students living over 3km from school, 87.1% agree they live too far to walk and 79.9% too far to cycle. The differences between active and non-active travellers living <=3km are significant for both walking and cycling: active travellers are less likely to agree that they live too far to walk or cycle.

Table 26

Perceived versus actual distance to school for those living within 3km of the school

Actual Distance to School	**"I live too far from school to walk"**	**Active Commuter % (n)**	**Non-Active Commuter % (n)**	p
<=3km	% Agree	9.7 (6)	23.0 (23)	.022*
	% Disagree	80.6 (50)	60.0 (60)	
>3km	% Agree	No participants commute over 3km	87.1 (142)	
	% Disagree		11.0 (18)	
Actual Distance to School	**"I live too far from school to cycle"**	**Active Commuter % (n)**	**Non-Active Commuter % (n)**	**p**
<=3km	% Agree	1.6 (1)	15.2 (15)	.016*
	% Disagree	83.9 (52)	68.7 (68)	
>3km	% Agree	No participants commute over 3km	79.9 (131)	
	% Strongly Disagree or disagree		12.8 (21)	

*p<.05

4.4.8 Estimates of distance travelled

The overall median estimated distance from school was 5.0km (IQR 7.6km) while the actual median distance was 3.0km (IQR 7.23). The median difference between estimated and actual distance was 0.5km (IQR 3.10). *Table 27* shows the median actual and estimated distances for gender, age and gender/age combined along with the median difference between both. Girls tended to have bigger differences between the actual and estimated distances; overall and when broken down into gender/age. The 15-16 year old boys had the smallest median difference of .25km.

Table 27

Median (IQR) actual and estimated distance between the home and school.

	n	**Distance Actual Median (IQR)**	**Distance Estimate Median (IQR)**	**Median Difference (IQR)**
Girls	144	5.10 (9.43)	6.40 (12.00)	.75 (4.27)
Boys	110	2.75 (4.4)	4.0 (5.0)	.30 (2.75)
13-14 year olds	157	2.8 (6.5)	5.0 (6.12)	.40 (3.10)
15-16 year olds	97	5.10 (7.95)	6.0 (9.0)	.6 (3.30)
13-14 girls	83	7.0 (12.55)	6.0 (12.50)	.60 (4.70)
13-14 boys	74	4.25 (6.03)	4.0 (4.1)	.30 (2.83)
15-16 girls	61	6.50 (10.7)	3.6 (8.6)	.80 (3.85)
15-16 boys	36	2.85 (4.40)	2.60 (3.87)	.25 (2.75)

The Bland Altman method was used to examine the relationship between the actual and estimates of distance travelled. The difference between the distances were plotted against the mean of both actual and estimated distance travelled to school (*Figure 17).* The Bland-Altman plot for distance travelled demonstrated a mean difference of 1.49 km ± 4.52km, with narrow limits of agreement ranging from 0.93 to 2.05 km. This indicated that participants estimated 1.49km more than the actual distance they travelled to school.

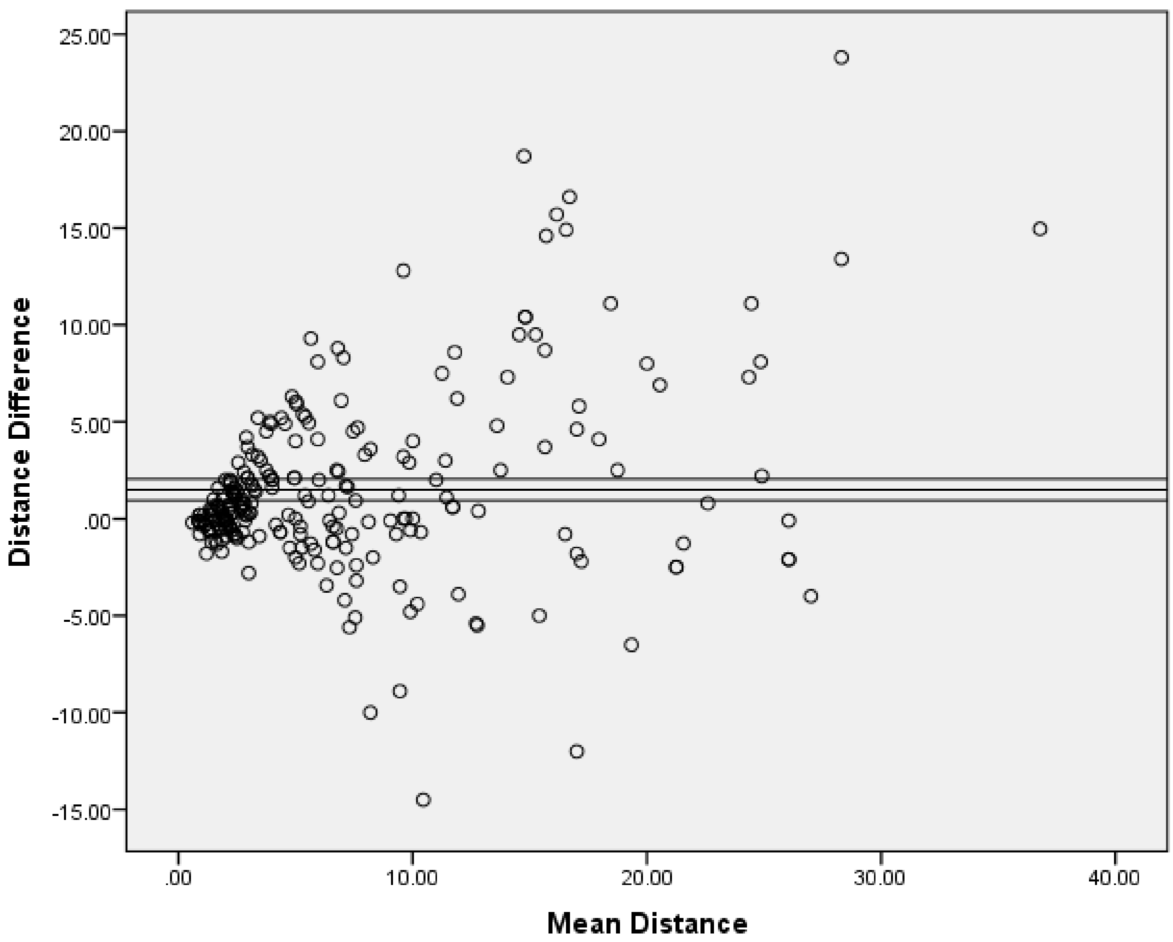

Figure 17

Bland Altman plot of actual versus estimated distance travelled to school

The median percent error between actual and esimated distance was 17.65% (IQR 91.59); i.e. students overestimated by an average of 17.65%. *Figure 18* shows the percent error by gender, age and gender/age combined. While there was no significant differences between any of the groups, girls had higher error rates than boys; both overall when comparing gender and also when stratified by gender and age. There was no difference between the age groups. The 15-16 year old boys had the lowest percent error (9.77%).

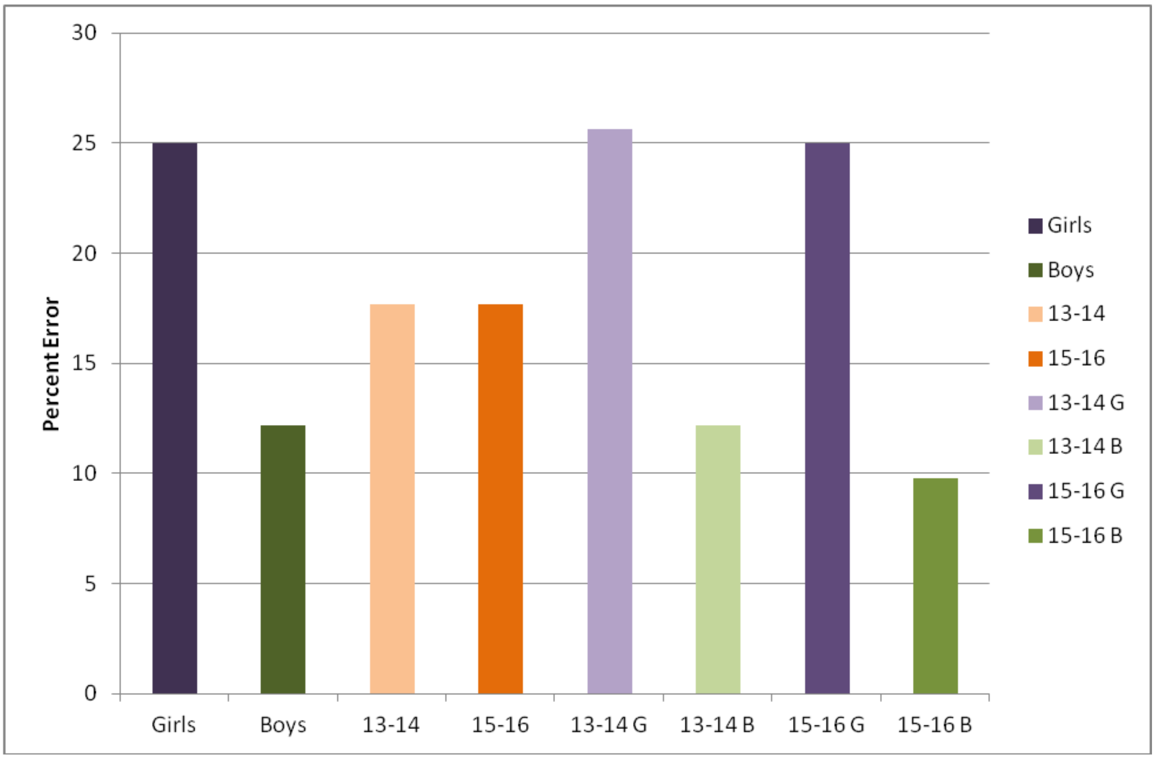

Figure 18

Percent error between distance actual and estimated distance from home to school

The percent error comparison between those who active travel and those who do not is shown in *Figure 19.* Those who participate in AT had higher percent error in their estimates of distance travelled than those who did not; overall, by gender and by gender/age combined, however, none of these differences were significant. The 15-16 year old AT group had over 33% error, which was over twice that of the non-active travel group. Boys who travelled by motorised means had the lowest percent error of 7.1%.

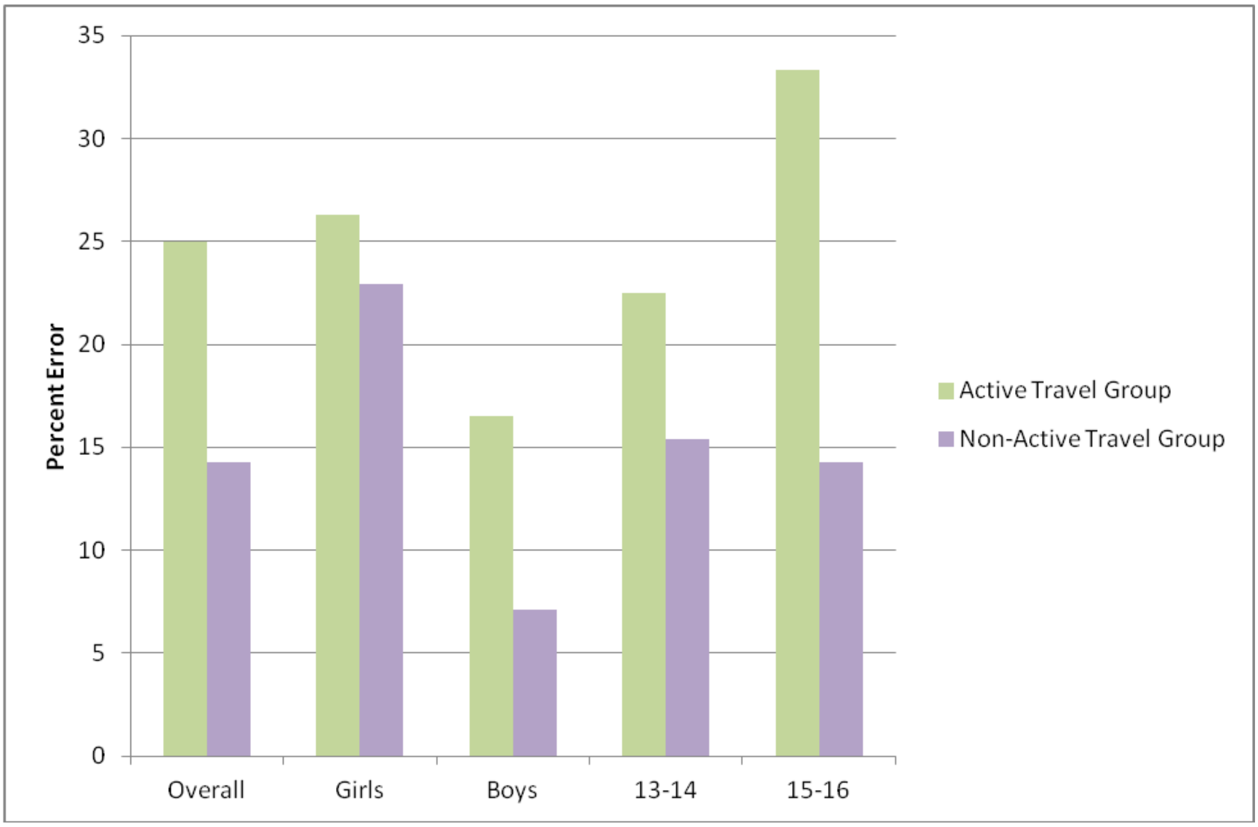

Figure 19

Comparison between the AT and non-AT groups percent error in the actual and estimated distance from home to school

4.4.9 Summary of AT Data

Boys spent significantly more time daily than girls in both walking and cycling for transport. Almost two-thirds of students travelled to school by car; only 5 out of the total 362 respondents cycled to school. Total PA for the whole group and all subgroups who actively travelled was on average 50 minutes more than those who did not take part in AT. When estimating the distance travelled to school, students on average reported 1.49km more than the actual distance travelled. Girls and the AT group tended to have a higher error rate in estimating distance travelled than boys and the non-AT group.

Chapter Five

5.0 Discussion

This study was part of a larger active travel survey that used the IPAQ-A questionnaire to ascertain levels of PA and active travel. Questionnaires are suitable for surveys of large populations, but cross validating against an objective measure, such as accelerometry is important and useful for interpretation of study findings. The IPAQ-A is a PA self-report questionnaire while the ActivPAL accelerometer measures PA and SB objectively and is considered a valid and reliable objective mode of PA measurement. Validation of the IPAQ-A with accelerometers has not been done in an Irish adolescent population to date.

The IPAQ-A was completed by 362 adolescents (61.9% girls, 38.1% boys), while there were 49 adolescents (41% girls, 59% boys) with valid accelerometer data. Accelerometry data suggested less PA behaviour in the sample than that collected by the IPAQ-A, with a weak relationship found between both measurement instruments. IPAQ-A data indicated that boys were more active than girls while the accelerometer data indicated similar overall PA levels for both sexes but higher MVPA levels in girls. Using the objective accelerometer data, there was a low level of adherence to the guidelines for PA (10.2%). Active travel was particularly low among the whole group, and especially among girls.

The purpose of this final chapter is to explain and clarify the results presented in chapter four and relate it to other research in this area.

5.1 Validation of the IPAQ-A

The study design was such that the IPAQ-A was filled out on the day of return of the monitor and therefore both methods refer to the same time period. Despite this, there were large inter-individual and overall differences between the IPAQ-A and ActivPAL for both total PA and MVPA. Overall, this study found weak to moderate correlations between instruments for both total PA and MVPA. The correlation coefficients found ranging from -.061 to .327 for total PA are similar to other validation studies examining the relationship between self-report questionnaires and accelerometers. For example, Ekelund et al. (2006) reported correlation coefficients ranging from 0.16 to 0.35, indicating moderate criterion validity. Similarly, Craig et al. (2003) had a median correlation value of 0.30 which they concluded was comparable to most other self-report validation studies. More recent studies, including Boon et al. (2010), Ottavaere et al. (2011b) and Hagstromer et al. (2008) all have similar correlation coefficients, but the latter study found lower correlations between instruments in younger adolescents. This was also apparent in this study, where correlations were lower for the younger age group (.091) compared to the older adolescents (.327). Despite this, the findings in this research showed that the younger age group reported a -0.4% difference in mean minutes of total PA while the older adolescent group had a percent error of 30.9%. There were large individual differences in the younger age group, and it is possible that the small percent difference is a random result, as opposed to accuracy in estimating time spent in total PA by this age group.

Ottavaere et al. (2011b) also reported agreement between instruments in terms of percent difference between the Actigraph accelerometer and the IPAQ-A in MVPA and found a range of 21-41% difference between instruments in a large sample size of 2018 adolescents. In the current study, the percent difference between IPAQ-A mean minutes and ActivPAL mean minutes overall was 14% for total PA while the overall percent difference for MVPA was 103%. Therefore, it seems that there was more agreement between the instruments for total PA than MVPA. When looking at the differences between sub-groups, boys had the highest percent difference for both total PA and MVPA; 35.1% for total PA and 142.4% for MVPA, which is likely the cause for the greater anomaly between instruments overall for MVPA. Overall, this analysis indicates overestimation of PA in boys in the self report assessment.

However, in the current study, not all of the sub-groups had higher IPAQ-A scores when compared to ActivPAL; there was a 17% difference between the two measurement methods for girls, with the ActivPAL recording almost 20 minutes more total PA than that self-reported on the IPAQ-A questionnaire. This indicates possible under-estimation by girls in the IPAQ-A. In a similar study by Ottavaere et al. (2011b) the authors found that 15-17.5 year old girls underestimated their vigorous PA by 133% in the IPAQ-A questionnaire compared to ActiGraph accelerometer recorded PA (median 9 minutes and 12 minutes respectively). The authors did not express any possible reason for this, however, it may be that girls actually under-estimate and under-report their levels of PA. In fact, Woods et al. (2010), in an Irish study, found that girls were more likely to underestimate meeting the guidelines of PA by self report (13%) when compared to motion sensors (17%). It is possible that girls under-report due to under-confidence in relation to PA. A study by Jakobsson, Levin and Kotsadam (2013) on gender and overconfidence found that confidence in a task depends on the 'gender typedness' of a task. For example, they found that boys were over confident in their mathematics skills, while girls were under-confident whereas in social science ability, both boys and girls were overconfident. Therefore, it might be reasonable to assume that PA and sport are often seen as more masculine and so girls were under-confident in their questionnaire responses.

There are many other possible reasons for the differences observed between measurement methods. One such reason is over-reporting, which is apparent in this study particularly among boys and the younger adolescent group. A study by Rzewnicki et al. (2003) examined the problem of over-reporting with the IPAQ in a sample of adults (n=50) and found 40% of subjects over-reported vigorous and moderate PA while over two-thirds over-reported walking. Lee et al. (2011) conducted a review of validation studies of the IPAQ short form, and found an average overestimation by 84% of PA by self-report when compared to objectively measured PA. Other studies on adults have also found over-reporting on the IPAQ (Celis-Morales et al., 2012; Boon et al., 2010; Johnson-Kozlow et al., 2006). This over reporting is likely due to a social desirability bias which has been defined by Adams et al. (2005) as "the defensive tendency of individuals to portray themselves in keeping with perceived cultural norms". They found that social desirability was associated with over-reporting of PA by up to 11 minutes over a 7-day period in a group of adult women (n=81; Adams et al., 2005).

Failure to accurately recall time spent in PA is another possible reason for discrepancies between measurement methods. According to Hagstromer et al. (2006), participants may have difficulty recalling PA due to the accumulation of activities over a day, and the variety of activities throughout the day, especially those activities that are low and moderate in nature. Conversely, high intensity PA which is often more structured can be easier to recall (Hagstromer et al., 2006) and thus, some studies have reported higher correlations between self-report and accelerometers for MVPA (Ekelund et al., 2006) and vigorous PA (Hagstromer et al., 2006; Ottavaere et al., 2011b). This was not apparent in this study where correlations for MVPA ranged between -.013 to .302, which were similar to those for total PA. Ottavaere et al. (2011b) also suggest that rounding up of time spent in PA can contribute to the higher PA levels found in the IPAQ-A.

Furthermore, the IPAQ-A requires participants to record the time and frequency spent in activities of different intensities which can be very subjective. For example Johnson-Kozlow et al. (2006) found that the IPAQ (administered by telephone) overestimated total PA by 247% against that measured by accelerometer among adult women. One of the reasons proposed for the difference is that the accelerometer may under-estimate activities such as vacuuming, sweeping and climbing stairs which are listed as moderate intensity activity in the IPAQ but would be inaccurately classed as light PA by the accelerometer.

The current study found that younger adolescents only had 0.4% difference between measurement instruments while the older adolescent group had 30% difference for total PA. As previously mentioned, there were individual differences in the younger age group for total PA and therefore the difference of 0.4% is most likely down to coincidence rather than accuracy by this age group. However, there was a large difference between measurement methods between younger and older adolescents in MVPA (128% versus 79% differences between IPAQ-A and ActivPAL respectively). Studies have postulated that disparity in the understanding of the questions in the IPAQ-A is a possible valid reason for the differences found between younger and older adolescents; younger adolescents may not comprehend and interpret the concepts as easily as the older group (Hagstromer et al., 2008; Ottavaere et al., 2011b). The use of a single-item questionnaire may help overcome difficulties with understanding questions. Wanner et al. (2014) recently found that a single item PA question used in their study performed as well as other PA questionnaires. Another possible reason for the difference between younger and older participant responses could be the likelihood of older adolescents participating in more structured activity and exercise, while the younger cohort participate in more spontaneous activities, which can be more difficult to assess with the IPAQ-A (Hagstromer et al., 2008). In addition, the IPAQ was initially developed for use with adults, and while the IPAQ-A is adapted for use with adolescents, it is possible that it is more valid among an older adolescent population (Hagstromer et al., 2008).

However, not all of the error in relation to differences in PA recorded can be attributed to the IPAQ-A. Many studies have identified underestimation of PA by accelerometers as being one of the main factors in the difference in measured PA by self-report and accelerometry (Hagstromer et al., 2006; Ekelund et al., 2006; Hagstromer et al., 2008; Boon et al., 2010). It cannot be assumed that the accelerometer is measuring and depicting the same aspects of PA as the questionnaire; for example, the accelerometer cannot measure certain activities such as biking, water sports, arm intensive activities and climbing. Indeed, Slootmaker et al. (2009) showed that cycling was a significant contributor to the difference between questionnaires and accelerometers. They also suggested that differences could be due to participants removing the accelerometer while playing sports. The current study removed time spent cycling from the IPAQ-A data when comparing it to the ActivPAL data, in order to give a more accurate assessment of the levels of agreement between the two measurement instruments. Therefore, differences between the tools in this instance cannot be attributed to cycling.

According to Atienza et al. (2011), questionnaires measure a person's PA behaviour in relation to the frequency, intensity and duration of activity, but accelerometers capture actual movement from which PA is then established using various cut points. It is possible that the cut-points used to determine different levels of PA, can result in certain movements not being included in accelerometer data, even though a person might have reflected it in the self-report questionnaire. This is supported by Boon et al. (2010) who also indicates that using different cut-points can ultimately affect the agreement between measurement tools.

5.2 Physical Activity Profile

5.2.1 Physical Activity Domains (IPAQ-A)

Not many studies have been undertaken on adolescent physical activity domains. However, one large-scale study completed as part of the HELENA study by De Cocker et al. (2011) used the IPAQ-A to assess self-reported PA among 3051 European adolescents, and therefore will be used for comparison in this section of the discussion. The active travel domain will be discussed in section 5.6.

On average, participants engaged in a median of almost 130 minutes of total physical activity daily in the current study according to the IPAQ-A. Most PA was reported during school time (during physical education classes and break time). Housework and gardening contributed least to overall PA which De Cocker et al. (2011) attribute to only one question being asked on this domain, while other domains had more questions, in addition to the notion that adolescents are often not responsible for housework and gardening in the home.

Boys participated in almost 10 minutes more PA at school than girls daily. This figure is made up of PE class time and PA during breaks; there were no significant differences between the groups in relation to PA during break time. However, there were significant differences in relation to PE class time, with boys spending double the amount of time in PE weekly than girls (median 80 minutes and 40 minutes respectively). There was a similar trend for age; the older adolescents having almost twice the amount of weekly PE than their younger counterparts (70 minutes and 40 minutes respectively). This may be due to the higher proportion of activities associated with transition year (Fahey et al., 2005). The transition year in Irish secondary school occurs in Year 4, following a year of focus on state exams. During this year there is an emphasis on non-academic activities such as art, music and sports and leisure activities. Fahey et al. (2005) identified a 'transition year bounce' characterised by a spike in activity levels where one might expect PA levels to be decreasing as is found in many studies examining PA levels among adolescents (Woods et al., 2010; Colley et al., 2011).

When it came to leisure time PA, the overall median time was 29.29 min/day, which is considerably less than that, found in the HELENA study, which reported most PA during leisure-time (average of 69 min/day). There was no significant difference between sex and age groups, whereas De Cocker et al. (2011) found significant gender difference for leisure-time PA.

5.2.2 Daily MVPA

In Ireland, the Department of Health and Children recommend that children and adolescents participate in at least 60 minutes of moderate-to-vigorous activity (MVPA) daily (2009). In the current study, the average daily MVPA from the IPAQ-A data was 58.9 minutes. Olds et al. (2007) argue that there is a need for guidelines around how compliance to the recommendations is calculated by researchers. There are no clear indications of the number of days that need to be sampled to ascertain if guidelines are being met; is it every day, most days, an average of days sampled or 'child x day', i.e. the probability that a randomly selected child would meet the guidelines on a randomly chosen day. Olds et al. (2007) used these four methods to compare compliance to the guidelines in a sample of 13-19 year olds. Results found a range of 20 - 68% on MVPA compliance. They concluded that unless the same methods are used, results from different studies are not comparable (Olds et al., 2007). The current study averaged MVPA over the previous week by adding the weekly moderate and vigorous minutes and dividing by 7 for the IPAQ-A. Because questions on moderate and vigorous data are separate in the IPAQ-A, it is not possible to accurately determine the number of days over which MVPA takes place. Again, this makes it difficult to compare to other studies. Borraccino and colleagues (2009), in the HBSC study, asked particpants about their MVPA for at least 60 minutes during the past 7 days along with MVPA over a typical week. MVPA was described as "an activity that usually increases your heart rate and makes you get out of breath some of the time". The average number of days where participants met the MVPA guidelines was 3.82 among all 32 countries that participated, while for Irish participants this figure was 4.4 days. In the current study, calcuations of MVPA using the ActivPAL data was done by adding each valid days MVPA data and dividing by the relevant number of days. The overall mean daily MVPA was 35.3 minutes. A recent study conducted by Collings et al. (2014) in the UK found objectively-measured moderate and vigorous PA levels of 38 and 3.4 mins/day respectively, which is comparable with the current study.

A significant gender difference in MVPA daily was found in the IPAQ-A data betwen boys (65.0 minutes) and girls (56.07 minutes). Irrespective of how MVPA is calculated, this is a trend that is consistenly found in research studies (Woods et al., 2010; Colley et al., 2011; Gavin et al., 2013). In contrast, the ActivPAL data from the current study showed that girls, on average, spent about 4 minutes more time in MVPA than boys (38 minutes and 34 minutes respectively) which contradicts a lot of previous research that also used objective measures (Riddoch et al., 2004; Shiely and MacDonncha, 2009, Collings et al., 2014). However, a very recent study conducted in South Africa by Wushe, Moss and Monyeki (2014) found that adolescent girls were significantly more active than boys in MVPA (61.13 v 35.0 mins/day respectively, $p<0.05$). The Actiheart accelerometer was used to objectively measure PA in their study.

There are a number of possible reasons for the high levels of MVPA observed in girls in the current study. It may have been a particularly active group of girls; for example 9 of the girls sampled were in transition year which may have meant that they participated in a lot more PA than usual (due to the 'transition year bounce' as outlined in section 5.2). It is also possible that there is a cultural shift towards more females participating in sport and physical activity. Recent results from the interim report of the Irish Sports Monitor Survey (Ipsos MRBI, 2013) showed that females were more likely to have increased their participation since 2011, in particular, women aged 35 to 44, who saw a 10% increase in participation in just two years from 34% in 2011 to 44% in 2013. This survey only includes people over the age of 16 but there was no breakdown of participation across age in the interim report to identify age specific trends. The HBSC Ireland Trends Report 1998-2010: Child Health Behaviours, Outcomes and Contexts (Gavin et al., 2013) has revealed an increase from 53.4% in 2002 to 58.3% in 2010 in girls reporting being physically active on four out of the previous seven days. These figures highlight the importance of studies such as the current one in terms of monitoring participation levels, especially among girls.

Another possible reason for the higher MVPA recorded by ActivPAL in girls compared to boys is that the ActivPAL does not record time spent cycling. IPAQ-A results revealed that boys spent on average 13 minutes more cycling for transport daily.

5.2.3 Meeting the PA Guidelines

In relation to the percentage of participants meeting the guidelines i.e. 60 minutes of MVPA daily, 49.8% of participants in the self-report data accumulated 60 minutes per day, while for the accelerometer data this figure was just 10.2%. Shiely and MacDonncha (2009) also found a discrepancy between self report and objective measurements in a study of Irish adolescents. Their study compared self-report to objectively measured PA via heart rate monitoring and found that approximately 11% of their participants met the international guidelines of moderate intensity PA as measured by self-report; however, no subjects met the guidelines according to the objective HR monitoring. Another Irish study, the CSPPA study (Woods et al., 2010), also reported low proportions of students 'self-reporting' meeting the guidelines by self report (12% of post-primary school children). The CSPPA study used a self-report questionnaire to assess PA participation and validity checks were undertaken using motion sensors (a combination of accelerometers and pedometers) to ensure accuracy of the self-report data.

As indicated above, the ActivPAL data revealed that the percentage of students meeting the guidelines (10.2%) was much lower than that reported by the IPAQ-A. Girls were more likely to meet the recommendations according to the ActivPAL data than boys (15% and 7% respectively). This is not suprising given the higher levels of PA in girls, as discussed earlier It is important to note that the current guidelines for daily PA are based on self-report activity measures and Celis-Morales et al. (2012) suggest that recommended sufficient activity guidelines based on objectively measured activity are likely to be lower than that for self report, which has also been noted by Troiano et al. (2008) and Atienza et al. (2011). Troiano et al. (2008), state that objectively measured epidemiological associations between PA and health might actually alter the current recommendations. They proposed that less than 30 minutes per day of accelerometer-measured PA could provide considerable health benefits because it corresponds to higher levels of self-reported PA.

5.2.4 Steps

Physical activity was also calculated in terms of steps with the ActivPAL. The mean average number of steps derived from the ActivPAL was 10475 steps per day, with no significant differences by age or gender. Interpretation of step-counts derived from accelerometers should be done with caution. While the ActivPAL has been shown to appropriately measure steps in free-living conditions, results should not be used to classify activity levels based on generic step count thresholds, or compared to step counts from pedometers (Oliver, 2011). For example, Tudor-Locke, Williams, Reis and Pluto (2002) found an average difference of 2,000 steps in data dervied from a pedometer and accelerometer. While 10,000 steps have been used as the level that equals one hour of moderate activity for adults, this figure may be too low for children (Armstrong and Welsman, 2006). Step counts specific to the ActivPAL which correspond to thresholds of activity need to be developed.

5.3 Sedentary Behaviour

The use of accelerometers to measure sedentary behaviour (SB) enables researchers to directly measure the total time spent in very low levels of activity during waking hours, whereas self-report instruments tend to measure a limited number of behaviours, such as TV viewing and computer use (Matthews et al., 2008). In a systematic review of SB and health indicators in adolescents aged 15-17 years, conducted by Tremblay et al., (2011), very few studies used objective measures to assess SB, which was the only measurement tool adopted in this study. Tremblay et al., (2011), found that of the studies that did use objective measures, up to 9 hours per day was spent being sedentary. The current study found the average daily time spent in SB was 9.6 hours which is slightly higher than many other accelerometer studies measuring SB. A recent Irish study by Harrington et al. (2011) is one of the first to have used the ActivPAL acceleromter to measure SB in adolescent females (n=111). The authors found that the mean time spent sedentary over a weekday was 18.8 hours while over the weekend this was 18.9 hours. This time also includes sleeping time, and thus cannot be compared to the current study which presented sedentary behaviour during waking time. A lot of other Irish data in relation to SB has been recorded through self-report, which makes it difficult to compare to the current study.

A recent study in the UK by Collings et al. (2014) found adolescents' sedentary time during waking hours was 364 mins/day (just over 6 hours) as measured by accelerometers. This finding is less than many other studies such as those listed above and the authors suggested a number of possible reasons for this such as the type of monitor used and its placement, seasonality, data modelling and reduction in addition to geographic location and fitness levels. Our study was conducted in September and October and therefore seasonality may have had an impact on results as the evenings get progressively darker and the weather gets colder at this time of year. According to Collings et al. (2014) variations in study results of SB due to seasonality has rarely been researched. They found that during school time, SB was higher in adolescents in spring-time compared to summer. They did not have any data for August and relatively few observations from the colder months and so were unable to comment on these time points.

A slight yet insignificant gender difference in SB was apparent in this research with girls recording an average of 9.5 sedentary hours and boys recording 9.72 sedentary hours daily. This corresponds to a mean difference of approximately 13 minutes less time spent sedentary per day for girls. This is in contrast to common findings in SB research among adolesents where boys spent less time engaged in SB than girls (Matthews et al., 2008; Woods et al., 2010; Colley et al., 2011; Ruiz et al., 2011; Collings et al., 2014). Woods et al. (2010) found that girls spent more time studying than boys and that as children progressed through the school cycle, the amount of homework increased (with the exception of transition year). Similarly Fahey et al. (2005) also found that girls studied more than boys - with 30% of them studying 3 or more hours per day compared to 17% of boys. Time spent doing homework increased over the school cycle with the exception of transition year, where there was a decrease (Fahey et al., 2005). It is possible that because the current study sample comprised only second years and transition year students, that not as much time would have been spent on homework than if they were in exam years or 5th year. Also, while SB and PA are not direct correlates of each other, it is possible that girls spent more time in objectively recorded MVPA and thus, had less time to engaging in SB than boys. There are other studies using objective measures that have found no difference between girls and boys SB. For example, Colley et al. (2013) found no difference in average daily sedentary time between boys and girls. Similarly, no differences in accelerometer-measured sedentary time were found between boys and girls aged 8-11 years in a study by Saunders et al. (2013b).

In the current study, time spent in SB did not differ between age groups. This contradicts a lot of adolescent research findings that report that SB increases with age (Woods et al., 2010; Colley et al., 2011; Ruiz et al., 2011). Ortega et al., (2013) found a decrease in MVPA coupled with an increase in SB in a cohort study which objectively measured MVPA and sedentary time in children and adolescents. They indicated that one of the reasons for a rise in SB with age is due to the increased academic requirements though adolescence. Similarly, Woods et al. (2010) found that time spent in SB increased with age along with a concomitant decrese in PA and suggested that it was due to the low level of PA and high screen time among the study sample. As previously mentioned, the study sample comprised second and transition year students; transition year students would not be representative of the older adolescent groups in terms of time spent in the classroom or doing homework, so it is difficult to compare the findings of SB and age with other studies.

5.3.1 Sedentary Bouts

A sedentary bout refers to a period of time spent sitting/lying. Therefore, examining bouts of sedentary activity will assist in understanding how SB occurs. In the current research, the mean number of sedentary bouts per day was 66.9. Girls had signficantly more bouts than boys (72 and 62 bouts respectively). When the length of bouts is examined, girls have significantly more shorter bouts (0-20 minutes) than boys; whereas boys have more bouts than girls in all the other time categories. This explains why girls have more bouts but yet less overall time spent in SB. However, the number of bouts is higher than other comparable studies. For example, Harrington et al. (2011) found that the mean number of sedentary bouts per day was 53 during the week and 49 at weekends in their study of adolescent females. Mitchell, Pate, Beets and Nader (2013) found that blocks of of SB lasting ≥30 minutes increased with age for both boys and girls. Our study found that the older adolescent group had more bouts of SB in the >40 and > 60 minute categories, with a significant difference between the age groups for number of bouts over 60 minutes. Therefore, while the curent study did not find an increase in total sedentary time daily with age, the lengths of the bouts of SB seemed to increase with age which may have important health implications.

The measurement of sedentary bouts is important as their duration can have a negative impact on health. Colley et al. (2013) conducted a study to examine the relationship between accelerometer-measured patterns of sedentary time and health risk in children and youth (n=1,608) in Canada and found that extended bouts of sedentary time of at least 40 minutes, occuring after 3pm on weekdays, were positively associated with waist circumference in boys aged 11-14 years old. Additinally, prolonged bouts that were at least 80 minutes long were positively associated with both waist circumference and BMI (in 11-14 year old boys). Similarly, Cliff et al. (2014) in a sample of obese/overweight children found that the total sedentary time and 30 minute bouts of SB were moderately and inversely associated with HDL cholesterol.

5.3.2 Breaks in Sedentary Time

Breaks in sedentary activity refer to interruptions in sedentary time. The current study found that the mean number of sedentary breaks was 58.7 per day. The mean break duration was 5.4

minutes. These findings are comparable to a study by Harrington et al. (2011), which found mean number of breaks during the week of 55 and 50 during the weekend while the mean length of break was 6.5 minutes during the week and 6.7 minutes at the weekend. Colley et al. (2013), however, found a greater number of sedentary breaks in their study with approximately 80 breaks per day. However, findings were similar to the current study in that girls had significantly more breaks than boys (64 and 55 breaks per day respectively). This may be related to girls having less total sedentary time daily than boys and also linked to the higher activity levels in girls found in this study.

Information on the number of breaks in sedentary time is important, as they have been found to be related to metabolic risk factors. For example, Healy et al. (2008) reported on objectively-measured breaks in sedentary time and their relationship with metabolic outcomes and found that more interruptions in sedentary time were positively associated with metabolic risk indicators among adults. One of the possible reasons put forward for this was that there may be higher energy expenditure in those people who took more frequent breaks. Findings from animal studies have also shown suppression of skeletal muscle lipoprotein lipase (LPL) during inactivity (Bey and Hamilton, 2003), which is linked with hypertension, metabolic syndrome and coronary artery disease in many human studies. Findings from the Healy et al. study (2008) also showed that people in the highest quartile for break frequency had a mean of 5.9cm lower waist circumference than those who were in the lowest quartile.

Breaks in sedentary time have also been linked with metabolic risk factors in children. Saunders et al. (2013b) studied the association of SB, sedentary bouts and breaks in sedentary time with cardio-metabolic risk in children aged 8-11 years with a family history of obesity. Findings showed that irrespective of total sedentary time and PA; breaks in sedentary time and short bouts of sedentary behaviour between 1-4 minutes were correlated with reduced cardio-metabolic risk and lower BMI. The authors suggested that children who regularly break up their sedentary time might have reduced cardio-metabolic risk factors over those who do not. Carson and Jansson (2011) did not find an association between breaks in sedentary time and cardio-metabolic risk in their study on 6-19 year olds.

This research found no difference in sedentary breaks between the age groups. Breaks in sedentary time were found to decrease with age by Kwon et al. (2012) who carried out a longitudinal study using accelerometry by collecting data at ages 5,8,11,13 and 15 years of age (approximately). Results showed a decline by >200 breaks per day over the 10 year study period. The frequency of sedentary breaks was both highly and adversely associated with sedentary time; thus indicating possible increase in prolonged SB such as watching TV or using a computer as children move into adolescence.

5.4 Total Active Travel Daily

In Ireland, there is considerable potential to increase the numbers of people who actively travel because currently most journeys are made by car (CSO, 2011). A particularly appropriate target group and journey for increased AT are young people and their commute to school. As noted previously, young people should participate in at least 60 minutes of PA per day to maintain good health. Importantly, children and adolescents who actively travel to school are more likely to accumulate more minutes of PA and have better cardio-respiratory fitness than those who do not (Davison et al., 2008). In the current study, all adolescents spent a median of 17.14 minutes daily using their bike or walking to get somewhere. The average (median) time spent walking was also 17.14 minutes daily.

Participation in cycling and walking was lower than that reported by Chillón et al. (2011b) in their study on active commuting and PA (part of the bigger HELENA study which used the IPAQ-A to assess travel behaviour in adolescents from 10 European cities (n=3112)). They found that adolescents reported an average (median) of 30 minutes walking for transport each day, with no significant differences found for gender or age. In contrast, the current study found that boys and the older adolescent group spent more time walking than girls and the 13-14 year olds. When it came to biking, girls spent almost 12.5 minutes less than boys per day cycling in the current study; there was no difference between age groups. These results are comparable to Chillón et al. (2011b) who also found that boys spent significantly more time cycling than girls per day. Additionally, they found that younger adolescents spent more time cycling than older adolescents.

While there has been much research done on the relationship between mode of transport to school and PA, Chillon et al. (2011b) were possibly the first to examine total daily active travel with PA using self report. In the current study, AT throughout the day was positively correlated with total PA, MVPA, moderate PA and vigorous PA; overall, and for all sub-groups with the exception of vigorous PA among boys and the 15-16 year olds. Chillón et al., (2011b) also found that adolescents who spent time actively travelling had higher levels of PA daily; however, in contrast to the current study, they found that, for boys, active travel PA had a greater effect on vigorous

PA in boys than girls. The current study examined self-reported AT and PA while Chillón et al., (2011b) used self-reported AT and objectively measured PA.

5.4.1 Mode of Transport to School

The current study also examined mode of travel to school and found that 19.9% of students walked or cycled to school; 18.5% walked while just 1.4% cycled. On average, studies have found that between 15% - 39% of adolescents actively travel to school in Ireland (Woods et al., 2010; Department for Regional Development, 2014). Figures for walking range between 15% (Department for Regional Development, 2014) to 40% (Woods et al., 2010) while figures for cycling range between 0% (Department for Regional Development, 2014) to 5% (Woods et al., 2010). Across Europe, AT, particularly cycling, is much higher, among adolescents. Cooper et al. (2006) found that, in Denmark, 85% of girls AT to school (64% cycled, 21% walked) and 88% of boys (67% cycle, 21% walk). In Belgium, 58.4% of older adolescent's aged 17-18 travel actively to school; 6.6% walked and 51.8% cycled (Van Dyck et al., 2010). Østergaard et al. (2013) found that 42% and 23.3 % walked and cycled to school respectively in Norway. Cooper et al. (2006) put forward number of reasons for high prevalence of cycling in Denmark; tradition in the country, cycle rack provision, well maintained and protected cycle lanes, priority for cyclists over other road users, culture of encouragement of cycling. They suggested poor levels of cycling in the likes of the UK probably due to high traffic volumes and poor provisions for cyclists.

In the current study, both schools surveyed service rural and urban areas and the median distance to school was 9.25km. Therefore, it might not be feasible for a lot of students to actively travel to school. The very low levels of cycling could have been due to a lack of provision for cyclists; for example there were no cycle lanes. Also, at the time of the study, there was no active travel plan in place in County Carlow; therefore there would not have been any promotion of walking and cycling in the town.

Anecdotally, weather is often cited as a reason for not walking or cycling for transport. Over four fifths of students in the current study agreed that they did not like to walk or cycle to school when the weather is bad. According to Børrestad, Andersen and Bere (2011) weather has not received much attention in research as a possible environmental determinant of AT which might be due to the fact that it is non-modifiable. However, a number of recent studies in the US and Europe have studied the effect of seasons and their associated weather on AT. Yang, Roux and Bingham

(2011) looked at the variation in AT by month using data from the National Household Travel Survey 2001 in the US. The study focussed on four groups; children, adolescents, adults and the elderly. Children and adolescents had a greater response to seasonality than other age groups. Similarly Børrestad et al. (2011), examined the prevalence of AT to school in relation to a number of factors including season in a cross sectional study of 10-12 year olds. They found that 75% of participants were classed as active travellers over the full school year; however, there were obvious seasonal patterns, especially for cycling. During Autumn and Spring, cycling was the dominant mode of transport (52% and 51% respectively), however during winter this number was just 3%. To offset some of this decrease, the number of students walking rose from 40% to 47% during the winter. In New Zealand, Tin Tin, Woodward, Robinson and Ameratunga (2012) conducted an ecological study on the temporal, season and weather effect on cycle volume. Data was collected by a cycle count on Tamaki Drive in Auckland and weather data was collected from the National Climate Database over a one year period. Weather variables significantly affected both hourly and daily cycle patterns ($p<0.0001$). For example, cycle volumes increased by 2.6% daily for each 1-degree increase in temperature but decreased by 1.5% for 1mm increase in rain. There was a 26.2% increase in cycle volumes with an hour of sunshine compared to no sunshine. Data in the current study was collected in late September and October, which might have affected the numbers of students actively travelling; especially into October as it gets colder and the mornings and evenings get progressively darker.

5.4.2Active Travel to School and Physical Activity

In the current study, the overall total PA for those who travel actively to school was on average 50 minutes more daily than those who travelled to school by motorised means. While not significant, higher MVPA values among those who AT to school were also found in the current study. It is not known whether the difference between active and non active travellers is down to the PA accumulated on the journey to school. Other studies have also found AT to school to be linked with higher PA levels. For example, Alexander et al. (2005) found that walking to school was positively associated with higher overall MVPA throughout the day compared to motorised travel to school. The authors suggest that walking to school could make people more appreciative of PA and walking in the morning could encourage someone to do further activity during the day, although these propositions were not investigated. Cooper et al. (2006) found that, while not statistically significant, adolescents who walked to school had consistently higher MVPA values than those who cycled or used motorised means to get to school. The differences found for cycling may be due to the use of limitations of accelerometers to record PA from cycling. Van Dyck et al. (2010) found that AT to school had a positive relationship with total PA and a longitudinal study by Carver et al. (2011) showed that AT was positively linked with MVPA for boys and girls in later adolescence.

5.4.3 Active Travel to School and Gender

In the current study, boys were more likely to travel actively to school which is consistent with other active travel research (Nelson et al., 2008; Woods et al., 2010; Silva et al., 2011; Clarke et al., 2013). In a review of quantitative and qualitative research on factors that influence walking and biking to school, Stewart et al. (2012) found that gender was never reported as a barrier to AT to school in qualitative research. However, they did suggest that parental fears might explain correlational findings in quantitative research that girls were less likely to AT to school than boys. Similarly, one of the reasons put forward by Davison et al. (2008) for the higher prevalence of boys walking to school than girls is possibly that parents are more protective of girls and can often place more limits on girls in relation to travelling alone. However, not all studies have found differences between sexes. In Ireland, Woods et al. (2004) found that girls were as likely as boys to walk or cycle to school. Østergaard et al. (2013) found no significant differences between sexes in relation to mode to transport in Norway.

5.4.4 Active Travel to School and Age

Younger adolescents in the current study were more likely to actively travel to school than the older cohort, which is a similar finding to other studies such as Silva et al. (2011). The HBSC study (Clarke et al., 2013) also reported a slight decrease in AT between younger and older adolescent groups. Among the 12-14 year old age group, 26% travelled actively to school while 24% of the 15-17 year olds walked/cycled to school. In contrast, the CSPPA study found that the age-related decrease seen in other forms of PA was not seen in AT as similar numbers of 10-18 year olds travelled actively to school (Woods et al., 2010). Overall, existing research on the relationship between age and active travel is unclear. Davison et al. (2008) suggest that this relationship is not linear. It is possible that increases in AT with age may be linked with independent mobility until such time that adolescents reach the age where they can apply for drivers licence and drive themselves to school. In Australia, Olds et al. (2009) proposed that the increase in passive travel from age 15 in their study may be due to the number of adolescents who got their drivers licences around age 16. In the current study, the older adolescents were 15-16 years old and in Ireland, a provisional licence cannot be applied for until age 17, therefore any potential decrease in AT due to driving has not yet been realised.

5.4.5 Distance to School

Distance to school is consistently associated with mode of transport to school (Nelson et al., 2008; Woods et al., 2010; Børrestad et al., 2011; Silva et al., 2011) and according to Davison et al. (2008), longer distances to school are associated with lower levels of AT to school. In the current study, the average (median) distance to school for all participants was 9.25 km. According to the UK National Travel Survey (Department for Transport, 2013), the average distance to school for secondary students was 3.4 miles (5.47 km). In Belgium the average distance to school was 6.57 (±6.17) km to school (Van Dyck et al., 2010); both lower than the distance in this study, which may indicate why AT is lower in Ireland than these countries. Indeed, amongst those who do actively commute, the average (median) distance to school was 1.75 km and all students who actively travelled lived within 3km of school. Similarly, the Take Part study found the average distance for walking was 1.9 km and cycling was 3.4 km (Woods et al., 2004). Van Dyck et al. (2011) found the average distances for walking to be 1.31 (± 1.03) km and 4.80 (±2.87) km for cycling.

A number of studies have looked at determining the criterion distance for AT to school. In Ireland, Nelson et al. (2008) collected self-report data from 4013 adolescents aged 15-17 year olds in relation to distance and mode of transport to school along with barriers to AT. The criterion distance for walking was ≤ 2.4 km (1.5 miles) and for cycling was ≤ 4.0 km (2.5miles). In Belgium, criterion distance for AT to school was determined to be 8 km for cycling and 2 km for walking (Van Dyck et al., 2010). These figures should be taken into consideration by policy makers operating services such as the School Transport Schemes; where students living outside a certain distance from school are entitled to support for transport to school. In Ireland and England, this distance is set at 4.8km (Department of Education and Science) while in Denmark, where the prevalence of walking and cycling to school is over 85% for adolescents (Cooper et al., 2006) the limit is set at 5 miles (8.0 km) (Osborne, 2005).

According to Nelson et al. (2008) inaccurate perceptions of distance may actually affect mode of transport choice. Stigell and Schantz (2011) proposed that people who actively travel use mental or cognitive maps to estimate recalled distances. These cognitive distances, while based on actual distances, can be affected by the difficulty of the route i.e. the number of turns, crossroads etc which can make the route seem longer than in reality. Additionally, the mode of transport can affect the estimations; trips made using AT require more physical effort and can therefore be perceived as being longer than if made by motorised means. In the current study, the median estimated distance to school was 5.0 km while the median actual distance was 3.0 km. Therefore, it is possible that students in this study decided not to travel actively because they perceived the distance to be too far. The current study found a mean percent error between actual and estimated distances of 17.65%, compared to 14% reported by Stigell and Schantz (2011). In the current study, girls had higher error rates, but this difference was not significant. Similarly, Stigell and Schantz (2011) also found greater error among women, but again this was not significant. The general conclusion suggested by Stigell and Schantz (2011) was that people are generally poor at estimating distances.

5.5 Study Limitations

- The sample size of the study was small and the research was carried out in a specific setting. This limits the ability to make generalisations about the results to the wider adolescent population in Ireland.
- The sample sizes were unequal in terms of gender and age (i.e. more girls and younger participants).
- The use of cross sectional research does not allow for the establishment of causal relationships. While this study provides valuable insight into adolescent PA, SB and AT levels, interventions are now required to further gain insight into these relationships through longitudinal or experimental study designs.
- The questionnaire asks participants about the number of days and time spent 'normally' in different activities. However, among this population there may not be a 'normal' type of day which is evidenced by the number of bouts and breaks in SB found in the ActivPAL data.
- Self-report questionnaires are prone to both over/under reporting; therefore the subjective data may not be entirely accurate.

- Similarly, accelerometers are unable to record activities such as cycling and swimming/water sports, therefore they may underestimate participant's total physical activity.

- The IPAQ was initially developed for use with adults and then adapted for use with adolescents. It is possible that the younger adolescents may not have completely understood the questions.

- While 78 students participated in the accelerometer data collection, only 49 data sets were eligible for use due to compliance with wearing the device.

- Using transition year students may not accurately reflect the older adolescent population due to the increased activity associated with transition year.

- The cut-points used to classify activity intensity are possible limitations because using alternative levels could change the amount of activity per person thereby affecting the overall results of the study.

Chapter Six

6.0 Conclusions and Recommendations

The first research question of this study was to assess the PA and sedentary behaviour profiles of school going adolescents. One of the most notable findings from the accelerometer data, which is a valid and reliable mode of PA measurement, was that girls spent more time in MVPA and were more likely to meet the daily MVPA guidelines than boys. It will be interesting to see if future studies find that the traditional gap between boys and girls participation is narrowing, with girls becoming more active. The average daily MVPA was just 35 minutes as recorded objectively. With the knowledge that there is a high level of tracking of PA behaviour from adolescence into adulthood, it is important to encourage this age group to become regularly active. This study also found that adolescent boys and girls engaged in high levels of sedentary behaviour daily. Low levels of PA along with high levels of SB may impact negatively on adolescent health; at present and into the future which poses potential overburdening on an already hugely overloaded health system. This all highlights the immediate importance of increasing PA participation and decreasing SB among adolescents.

Research question two of the study was to investigate if there was a close relationship between the objective and subjective methods of physical activity measurement. Large inter-individual differences were found between both methods which could be attributed to a number of factors including over/under reporting of the questionnaire, understanding of the questions and inability of the accelerometer to record particular activities such as cycling. Criterion validity presented weak to moderate correlations between measurement methods. It seems that both methods have their own advantages such as questionnaires are suitable for large populations and can offer us insight into the context and type of activities performed while the accelerometers provide a method of objective data collection. Therefore, perhaps using both methods, wherever possible is the ideal solution.

The final research question of the study related to active travel (AT). Low levels of AT were found in the current study, which is similar to results from other studies in Ireland, but a lot lower than some of our European counterparts. This was most likely due to the catchment area which the schools serve. Almost 40% of students who lived within 3km of the school travelled actively. There is considerable potential to increase the numbers who actively travel by targeting the other 60% who live within this commutable distance. Girls were less likely to travel actively than boys and only five students in the whole study cycled to school. AT was associated with higher levels of PA. This all highlights the need to promote AT at both national and local level; with particular emphasis placed on encouraging more girls to get involved and initiatives to promote cycling to all. At a local level, Carlow were successful in securing funding for the implementation of an active travel plan incorporating both walking and cycling late in 2012. The plan aims to implement both infrastructural and behavioural change measures to improve AT within the town. This should help to increase the numbers of children who walk and cycle to school in this area. Other measures such as parking and traffic restrictions around schools make the roads safer to use for cyclists and pedestrians. Restricted car parking has been shown to significantly increase active travel in the workplace (Brockman and Fox, 2011).

As part of the AT section, estimated versus actual distance travelled was examined with students more likely to overestimate the distance they travelled to school. Interestingly, those who travelled by motorised means were more accurate than those who travelled on foot or by bike. Distance is often cited as a barrier to AT and if students base their decisions of how to travel to school on their perception of the distance they must travel, then it might be useful for schools to educate their students and assist them to ascertain how far they need to travel and if it is feasible to do so actively.

6.1 Recommendations for Future Research

The current study was cross sectional by design, which is ideal for establishing baseline measurements of PA, SB and AT behaviour. However, future longitudinal and interventional studies are needed in order to track these behaviours over time and evaluate the effectiveness of interventions to promote PA/decrease SB. It would be useful if these studies included measurements of health such as BMI, blood pressure and risk factors like smoking, alcohol use etc which would help to determine the relationship between PA, SB and health.

Standardised methods of measurement need to be established. This is true for both self-report and objective measures. There is a vast array of self-report measures used in research, often with differing terms and definitions, which make comparisons between studies difficult. As previously mentioned, the daily guidelines for MVPA are based on self-report, which also make it difficult to evaluate results when using objective measures. In relation to accelerometers, consensus on cut-points used for different intensities and ages need to be agreed, again to enable comparisons between research studies. Additionally, agreement on reporting criteria would be very useful in terms of comparing study results. So while some studies use the same measurement tool, the presentation of the results can differ greatly. For example, some people report daily figures, while others report weekly, minutes versus METs, different age categories are reported on etc which can make comparisons difficult.

With the constant advent of new phone and computer 'apps', there is potential around using apps to objectively measure PA and SB. Considering that accelerometer use can prove costly, and thus is often used on small study populations, the use of apps may facilitate objective measurement of larger samples. A recent paper published by Dunton et al. (2014) outlines their design and development of a new smartphone app called Mobile Teen that combines both objective and self-report assessment of PA. This app will use the phones built-in sensors to detect major changes in phone movement, after which the user is prompted to enter information about possible PA, SB or episodes of data loss. The app also allows the adolescents to interactively input information regarding their activity at the end of the day using cues from the phone to help recall the type, intensity and duration of these activities. Similarly, brands like Samsung, Apple and Sony have wrist based activity trackers which monitor activity and steps. Nolan, Mitchell and Doyle-Baker (2014) recently conducted a validity study of the accelerometer in the Apple iPhone/iPod Touch. Subjects performed treadmill walking and running at different speeds. Activity type was classified by the Apple devices with 99% accuracy while speed predictions had a bias of 0.02k $km.h^{-1}$ for walking and -0.03 $km.h^{-1}$ for running. The authors concluded that the iPhone/iPod Touch had the ability to calculate movements such as walking and running similar to other accelerometer-based measurement tools (Nolan et al., 2014) suggesting that these devices, and others like them, may in the future, enable easier and more affordable objective PA measurement among adolescents.

Further research in the area of sedentary behaviours needs to be carried out. Again, different definitions of SB are used and this needs to be addressed. Information on the prevalence of SB, the relationship between SB and PA and the health factors associated with SB would be useful along with what actually makes up SB time (e.g. television watching, mobile phone use, reading, sitting etc) and when it occurs (during school, weekdays, weekends etc). Specific guidelines on SB - like those for daily MVPA - could then be developed - which incorporate all aspects of SB - not just screen time, but inclusive of sitting time, reading etc.

Because the levels of AT are so low, especially for cycling, research into the barriers and facilitators of AT needs to be carried out among adolescents. This information could help policy makers at national level to develop and implement appropriate policies for this age group. It may also help schools and parents to identify ways of encouraging and promoting active travel to this cohort.

6.2 Recommendations for Interventions

As is evident from the results of the current study, intervention is required; firstly to increase PA among adolescents, secondly to reduce SB and finally to improve the levels of AT among this cohort. This can be done on a number of levels. At policy level, strategies to increase PA need to be developed. Alongside this, an implementation plan of the strategy is also required; too often, strategies are developed with realistic and achievable aims, however, there is no associated implementation plan which outlines how the aims and objectives of these strategies should be completed. Naidoo and Wills (2009) outline the four key stages for policy-making including: 1) Problem identification and recognition, 2) Policy formulation, 3) Policy implementation and 4) Policy evaluation. It is imperative that each of these stages is planned effectively and carried out thoroughly. In May 2013, a report card on PA in children and youth in Ireland was published which outlines current PA, SB, AT levels and will be useful in terms of baseline figures for comparisons into the future. At this level, strategies should also be developed to reduce sedentary behaviours. Guidelines around daily sedentary behaviour for adolescents should also be devised. A partnership approach is essential within a policy process (Naidoo and Wills, 2009) therefore, all policies and strategies should be developed via inter-agency and department cooperation to avoid duplication of resources and to ensure everyone is focused on the same goals.

The current recommendations for PE in Ireland are 120 minutes per week, however, according to the current study adolescents are only achieving about 60 minutes. Therefore, school based interventions could be used to increase the amount of time spent in PE class and/or increasing the number of days PE classes are offered. The Department of Education should look at standardising PE at second level so that all students can participate in adequate levels of PA during school time. At local levels, schools have an important role to play in implementing interventions to increase PA and decrease SB. According to Dobbins et al. (2013) there is some evidence to suggest that school-based PA interventions are associated with increases in PA daily, a reduction in TV viewing and improvement in aerobic capacity. The Department of Education and Science (2009) currently run the Active Schools Flag initiative which aims to promote PA in schools. While this initiative has potential benefits, monitoring and evaluation of the programme would be useful to see its effectiveness.

School time presents opportunities to be physically active not just during PE time, but also during breaks and after-school. Therefore, interventions to increase PA during these times should be developed. Also, because prolonged sitting has been linked with type 2 diabetes, metabolic syndrome, cardiovascular disease and obesity, breaks in sitting time during class could help to reduce the adverse effects of prolonged sitting. The Irish Heart Foundation have a 'Bizzy Breaks' programme for primary schools which contains activities designed to get students moving on the spot for 5-10 minutes. A programme such as this could be adapted for use in secondary schools to help break up sedentary sitting time.

Commuting to school presents an opportunity for increasing daily PA. While some students live too far to actively travel the whole way to school, there may be an opportunity to actively travel part of the way. For example, a student who gets driven to school could get dropped off further away from the school and they could walk the remainder of the journey. The low level of cycling also needs to be addressed; it is not clear from the current study why so few students cycle. However, it is possible that inadequate infrastructure is one of the reasons. At the time of the study, there were no cycle lanes around the schools surveyed. Here is where local government agencies have a role to play in promoting and facilitating AT. Schools have a part to play by ensuring there are facilities for bikes to be stored safely. As previously mentioned, distance has been shown to be a barrier to AT. The current study also found that students overestimated the distance between their home and school. Therefore, schools should also help students in educating students on the distance they travel and if it would be feasible for them to actively travel all or part of the way to school.

Anecdotally, the Bike to Work Scheme, which is a Government initiative that offers tax free bikes for cycling to work, has been hugely successful. Perhaps this scheme could be adopted and a 'Bike to School' scheme could be introduced. It could operate by offsetting the current costs against future tax credits, or parents could avail of the tax credits if they were working. Appropriate clothing for weather should be included with the scheme as over four-fifths of the students in the current study indicated they don't like to walk or cycle in bad weather; perhaps if they had the right attire for such weather, it might make AT more appealing. Another possibility would be for a scheme like the Dublin Bikes - which is a self-service bike rental system which enables people to commute around the city of Dublin. Bike stations could be set up in proximity to schools, and parents and public transport could drop children at the bike pick up areas where they would travel on to school.

Parents are often the decision makers in relation to their children's activities; therefore they must also be educated on the benefits of AT to school. In the current study, over 70% students said their parents were happy to drive them to school. Only one-third of students said their parents encourage them to cycle to places. School-led promotion of AT to school for both parents and students should be encouraged.

At a national and policy level, a lot of work has been done in terms of active travel through the Smarter Travel Programme run by the Department of Transport. Three areas (Limerick, Dungarvan and Westport) received funding of €23million to be spent over a 5 year period to promote cycling and walking and to decrease use of the car. The programme started in 2012 and anecdotal evidence suggests that it has been hugely successful to date. Irelands first National Cycle Policy Framework was also published under the Smarter Travel Programme with a vision to create cycle friendly cities, towns, villages and rural areas throughout Ireland. There is also a Green-Schools programme includes a Travel theme, and is funded by the Department of Transport, Tourism and Sport. Again, monitoring and evaluation of initiatives run under these programmes would provide valuable information to assist in increasing active travel.

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APPENDIX A

Literature Review: Developing a Protocol for Accelerometer Use

Selection of a Monitor

According to Matthews et al. (2012) the selection of a PA monitor for research studies should be based on the study objectives along with the availability of resources both to buy and use the systems. While the overall cost of the monitor (including associated costs such as belts, adhesives etc.) is a significant factor, it should not be the only one (Trost et al., 2005). Accelerometer size is important; they should be small and light and not interfere with daily activities (Plasqui and Westerterp, 2007). Both Ward et al. (2005) and Welk et al. (2012) suggest that the aims of the research should be the main determinant in choosing a monitor. Validity and reliability of the chosen monitor is also very important (Trost et al., 2005). Ultimately, there is a trade-off between the more basic monitors which may be less accurate for certain PA behaviours and the more expensive, onerous systems that provide greater precision (Mathews et al., 2012; Welk et al., 2012).

Distribution of Monitors

Monitors can be distributed face-to-face or by mail (Ward et al., 2005). Face-to-face is easier for small scale studies and allows demonstration of proper placement and the opportunity for questions and answers about the procedure. Some researchers distribute face-to-face and then provide a pre-paid envelope for returning the monitor thereby eliminating the need for a return visit (Trost et al., 2005). Irrespective of how the monitor is given out, an information sheet containing instructions for device care, contact details for researchers, a picture of proper site placement and positioning of the monitor should be given to all participants. In addition, a log book for recording when the monitor was put on and taken off should be given to participants to aid verification of compliance with the protocol, and which may also help if there are issues during data processing and interpretation (Mathews et al., 2012).

Monitor Placement

Where the accelerometer is placed on the body is dictated by the type of accelerometer used and the reason it is being used (Berlin et al., 2006; Mathews et al., 2012). Because of their small size, accelerometers can be worn in many locations; however, lower back/hip is the most common placement site with no calibration studies using other sites to develop the formulas needed to interpret data output (Ward et al., 2005). A lot of the literature pertaining to adults and children concur that waist-mounted devices are the best site placement; however, agreement on site placement is needed (Strath et al., 2012). A recent study by Cleland et al. (2013) examined the optimal placement of accelerometers to assess everyday activities. Tri-axial accelerometers were placed on 6 body locations (chest, hip, thigh, foot, wrist and lower back) and subjects performed a range of activities including walking, running, sitting, lying, standing and walking up and down stairs. Findings showed the hip location as the most accurate position for data collection, with only slight, but yet significantly better accuracy than the other monitor positions. Trost et al. (2005) suggested that the accelerometer should be worn as close as possible to the centre of mass of the body. While neither right nor left side monitor wearing has been favoured, a standard protocol should be agreed for consistency; the right side perhaps being the location of choice with most people being right-handed (Ward et al., 2005).

Compliance

For accurate PA measurement, compliance with wearing the monitor is crucial (Ward et al., 2005; Trost et al., 2005). Successful strategies to increase compliance have included phoning/texting participants to encourage wearing, incentives for wearing and return of monitors, and the filling in of log-books by participants (Ward et al., 2005).

Number of Days Monitoring

It is important that the number of days of monitoring adequately reflects a person's regular level of PA (Trost et al., 2005). A 7-day monitoring protocol has been used widely in PA measurement studies as it allows enough days to achieve intraclass correlations of more than 80% in most populations, in addition to providing information on both week and weekend days (Mathews et al., 2012). Considerations such as the battery life and maximum capacity of the monitor need to be taken into account when deciding on the number of days to measure (Berlin et al., 2006).

Trost et al. (2000) investigated the minimum number of day's measurement of PA using accelerometers that would be needed to represent habitual PA levels among children and adolescents. Results showed that between 4 and 5 days of monitoring was needed to achieve reliability of 0.80 in children, and between 8 and 9 days to achieve the same reliability in adolescents. They found that at all ages, the 7-day monitoring protocol provided acceptable estimates of MVPA daily (ICC = 0.76-0.86). More recently, Mattocks et al. (2008), in a large scale study (n=5595), found that 3 days monitoring gave acceptable levels of reliability (r=.7) using the Actigraph accelerometer among 11-year olds . This improved to 0.8 over 5 days monitoring, and 11 days were required for a reliability coefficient of 0.9. The authors reflected that while 3 days might be sufficient for large scale studies, those with smaller sample sizes might use more measurement days. Corder et al. (2008) recommend that at least 4 full days of monitoring, including one weekend day, would be the minimum protocol used.

Monitor Wear Time

While there is no defined guidelines for the amount of wear time needed to represent a valid day of measurement (Corder et al., 2008) the two sampling frames most often used by researchers are the 24-hour period, which includes both sleeping and waking time and the 10-hour day minimum which has recently emerged as a consensus for adequate wearing time (Mathews et al., 2012). The sampling threshold should be chosen based on the objectives of the study and the population being studied (Mathews et al., 2012).

Classification of non wear time

It is important to know when the accelerometer is worn to help researchers ascertain compliance and also to ensure participants' data can be used for analysis (Evenson and Terry, 2009). Non-wear times refer to instances during a monitoring day where perhaps the user removed the monitor and later replaced it, or it was disconnected accidentally from the wearer, or where it was not worn enough to represent a full days monitoring and therefore there is missing or incomplete data (Heil et al., 2012). An accelerometer will register zero counts over an epoch both when an accelerometer is not worn, but also when the participant is motionless (e.g. sleeping, sitting) (Evenson and Terry 2009). It is important that sedentary behaviour is not classed as non-wear because it means that valuable data will be discarded (Hutto et al., 2013).

While logs can be useful for tracking wearing time, it introduces an element of self-reporting which can hinder compliance, therefore, an alternative is to work out non-wear time based on the accelerometer data. However, there are no standardised processes for defining and assessing non wear time (Evenson and Terry 2009).

Hutto et al. (2013) compared five different accelerometer derived methods of identifying non-wear time and wear time using the Actical monitor and daily log sheets in a population of older adults (n=200). They found that at least 120 minutes of consecutive zero counts provided accurate estimates of wear and non-wear time for that particular population of older adults. Peeters et al. (2013) compared three methods of measuring non-wear time among office workers (n=45) using Actigraph accelerometers; automated, log-book, and a combination of the two. Automated alogorithms were used to identify consecutive zero bouts of 20, 60 and 90 minutes. The authors concluded that automated filters were as accurate as a combination of automated filters and log-boks in classifying wear time and recommended automatic filters based on 90 minutes of consecutive zero bouts for future studies. Other studies have defined 60 minutes of uninterrupted zero counts, such as Troiano et al. (2007), while studies on children have used 10 minutes or more of consecutive zero counts for classifying non-wear time (Trost et al., 2008; Steele et al., 2009). Mâsse et al. (2005) state the assumption that adults can remain still for longer periods than children, therefore it might be better to use longer bouts of zero counts with adults and older adults.

Spurious Data

Data that lie outside of realistic ranges should be cleaned (Ward et al., 2005). Evenson and Terry (2009) considered spurious data as non-wear time defined as one minute/epoch of activity bordered either side with consecutive zero counts. Mâsse et al. (2005) used 3 different algorithms to identify spurious data with a criteria of; ≥20,000 counts, ≥16,000 counts and ten minutes of continuous counts >0. They concluded that combining the approaches used in each algorithm would yield optimal data cleaning.

Expressing and Reporting Data

Knowing how to manage and interpret the considerable amount of data produced by accelerometers is a great challenge (Ward et al., 2005). Data from accelerometers can be expressed in a number of different ways including total counts or steps over a certain length of time, counts or steps per day/minutes, time spent in specific activity intensities, number and duration of activity bouts per day and estimates of EE (Berlin et al., 2006). Therefore it is important to decide on which measurement unit to report on so that comparisons can be made with other studies (Berlin et al., 2006; Strath et al., 2012)

APPENDIX B

School Recruitment Letter

Waterford Institute *of* Technology

Dear *Principal*,

I am currently completing a Research Masters on Physical Activity and Active Transport in Adolescents in Carlow/Kilkenny. In order to complete the research, I need to recruit participants from both a boy's and a girl's school in Carlow Town. The research itself will consist of the following:

1. A questionnaire to be completed by all second years and transition years (it takes approx 10-15 minutes to complete)
2. A sample of approximately 20 second years and 20 transition years to wear a small non-obtrusive portable device called an accelerometer for 7 days. The accelerometer measures the time a person spends walking, sitting, lying. (The data from the accelerometer will be validated against the information recorded in the questionnaires).

I would greatly appreciate your participation in this project. I have attempted to outline below some answers to further questions you may have.

When will the research take place?
We hope to conduct the research at the end of September/start of October.

Why should we be involved?
The information on physical activity and transport levels particular to your school will be made available to you. This will provide you with valuable information about how your students travel to school and how active they are. I will also be able to provide you with the Active Travel Education Materials which are currently being developed in WIT.

What do I need to do to be involved?
If you bring this to the attention of your Board of Management, they can consider and give consent to participation. I will have consent letters for parents which can be given to each student in 2nd and 4th year. This outlines further detail on the study and gives them the option to prevent their child from participating.

Thank you for taking the time to consider this research proposal. I look forward to meeting with you soon.

Yours Sincerely,

____

Niamh Spratt
Mob: 087 2079178
Email: niamh.spratt@itcarlow.ie

APPENDIX C

Information letters and consent forms

Waterford Institute *of* Technology

Information about the Physical Activity and Active Transport Research Study

Dear Parent / Guardian,

I am currently completing a Research Masters on Physical Activity and Active Transport in Adolescents in Carlow and Kilkenny. In order to complete the research, I am recruiting participants from both a boy's and a girl's school in the Carlow and Kilkenny Region. The research itself will consist of the following:

3. A questionnaire to be completed by all second years and transition years
4. A sample of approximately 20 second years and 20 transition years to wear a small non-obtrusive portable device called an ActivPAL accelerometer for 7 days. The accelerometer measures the time a person spends walking, sitting, lying.

I would greatly appreciate your child's participation in this project. I have attempted to outline below some answers to further questions you may have.

What is the research for?
To compare the physical activity levels of teenagers in Carlow and Kilkenny recorded by questionnaire and by wearing an ActivPAL.

What will happen if I allow my child to participate?
There are two parts to the study; the first part is the physical activity questionnaire which will be completed by ALL consenting students and takes about 10 – 15 mins to fill out. For the second part of the study, a sample of 20 students will be randomly selected to wear an ActivPAL accelerometer on their thigh for a period of 7 days in September/October before they complete the questionnaire in school.

How will my child's information be used?
Waterford Institute of Technology will protect all the information about your child. Their identity or personal information will not be revealed or published. The study findings will be presented in a postgraduate thesis, academic publications, conference papers and other scientific publications.

What do I need to do now?
There are two options available to you and your child which are outlined overleaf:

Option 1

If you are happy for your child to participate in both the **Questionnaire** and **Accelerometer** part of the study then you **do not have to do anything**.

If your child is selected to wear the accelerometer, they will be given additional information to share with you before participating.

Please note that participation in the study is completely voluntary and participants are free to withdraw at any time without giving a reason and without consequence.

Option 2

If you **do not wish** your child to participate in **ANY** part of this research project – please sign below and return to the school.

I **do not wish** my child to participate in the Phyisical Activity and Active Transport Research Study.

Students Name: ________________________________

Your Name: ____________________________________Signature: _________________________

Date: ____

Thanks for taking the time to read this and please don't hesitate to contact me if you have any further questions.

Niamh Spratt
Tel: 059 9175571 / Email: niamh.spratt@gmail.com

APPENDIX D

Self-report Questionnaire

Waterford Institute *of* Technology

Office use only

Physical Activity and Active Travel Survey

Questions about you

1. **What year are you in?**

   1st ❍ 2nd ❍ 3rd ❍ TY ❍ 5th ❍ 6th ❍

2. **What age are you?** __________ (years)

3. **What is your home address?** *Don't forget the house number if it has one!*
   (The reason we are asking for your address is so we can calculate the distances travelled to school by students. Your address will **not** be used for any other purpose).
   ____

   ____

   ____

Questions about how you travel TO school

4. How do you usually travel **TO** school? i.e. think about the longest part of your journey

   Walk ❍ Cycle ❍ Car ❍ Bus❍

5. How would you **prefer** to travel **TO** school?

   Walk ❍ Cycle ❍ Car ❍ Bus❍

6. How long does your journey take from your home to the school gate?

   ______ Minutes

7. Can you estimate the distance from your home to the school gate?

________ Kilometres **OR** ________ Miles

8. Do you own or have access to a bicycle? Yes ❍ No ❍

Questions about your thoughts on active travel

9. To what extent do you agree with the following statements about CYCLING to school?

	Agree strongly	Agree	Neither	Disagree	Disagree strongly
Cycling to school would be too tiring	❍	❍	❍	❍	❍
Cycling to school is not safe	❍	❍	❍	❍	❍
I am confident in my cycling ability	❍	❍	❍	❍	❍
I hate wearing a cycle helmet	❍	❍	❍	❍	❍
I don't like to cycle when the weather is bad	❍	❍	❍	❍	❍
I have lots of stuff to carry to school	❍	❍	❍	❍	❍
I couldn't be bothered cycling to school	❍	❍	❍	❍	❍
Cycling to school would take too long	❍	❍	❍	❍	❍
My friends would think I looked stupid if I cycled to school	❍	❍	❍	❍	❍
The clothes I wear make it hard to cycle	❍	❍	❍	❍	❍
Other students would think I looked stupid if I cycled to school	❍	❍	❍	❍	❍
My friends cycle to school	❍	❍	❍	❍	❍
Driving is the easiest way to get to school	❍	❍	❍	❍	❍
My parents/guardians encourage me to cycle to places	❍	❍	❍	❍	❍
Cycling to school would ruin my hair					
My parents/guardians are happy to drive me to school	❍	❍	❍	❍	❍
Cycling to school would ruin my make-up	❍	❍	❍	❍	❍

I worry about my bicycle being stolen in school	❍	❍	❍	❍	❍
There is a safe cycling route from my house to school	❍	❍	❍	❍	❍
There is a direct cycling route from my house to school	❍	❍	❍	❍	❍
I live too far away from school to cycle	❍	❍	❍	❍	❍

11. To what extent do you agree with the following statements about WALKING to school?

	Agree strongly	Agree	Neither	Disagree	Disagree strongly
Walking to school would be too tiring	❍	❍	❍	❍	❍
I don't like to walk when the weather is bad	❍	❍	❍	❍	❍
I have lots of stuff to carry to school	❍	❍	❍	❍	❍
I couldn't be bothered walking to school	❍	❍	❍	❍	❍
Walking to school would take too long	❍	❍	❍	❍	❍
My friends would think I looked stupid if I walked to school	❍	❍	❍	❍	❍
Other students would think I looked stupid if I walked to school	❍	❍	❍	❍	❍
My friends walk to school	❍	❍	❍	❍	❍
Driving is the coolest way to get to school	❍	❍	❍	❍	❍
My parents/guardians encourage me to walk to places	❍	❍	❍	❍	❍
Walking to school would ruin my hair					
My parents/guardians are happy to drive me to school	❍	❍	❍	❍	❍
Walking to school would ruin my make-up	❍	❍	❍	❍	❍
There is a safe walking route from my house to school	❍	❍	❍	❍	❍
There is a direct walking route from my house to school	❍	❍	❍	❍	❍
I live too far away from school to walk	❍	❍	❍	❍	❍

Questions about how active you are

The following questions are about all the **walking, vigorous and moderate physical activities** that you did **for at least 10 uninterrupted minutes in the last 7 days**.

Please do not include those activities that took less than 10 minutes per occasion. By the last 7 days we mean 5 school days and 2 weekend days.

The questions are divided into four groups and ask questions about

- physical activities you did during school time,
- physical activities you did in and around your home like housework and gardening
- physical activities you did to get to and from places,
- physical activities you did during leisure time (physical activities during play, sports, dancing, exercise and competition).

Physical Activity in School

This part is about the physical activities you did over the last 7 days during school hours (during class and during break-time). Transportation to and from school are **NOT** included.

A. During PE classes

12. How many **classes** (in school hours) of PE did you have during the last seven days**?**

❍ none	❍ 1	❍ 2	❍ 3	❍ 4	❍ Other ______

How much time did you spend in TOTAL during these PE classes on **physical activities** such as sport, running, playing or dancing? Give the total for the whole week, but count only the occasions that you were active for at least 10 uninterrupted minutes.

_____hours _____minutes physical activity during the last 7 days

B. During breaks

13. During the last 7 days, on how many days did you do the following, during **breaks** at school, **for at least 10 uninterrupted minutes?** Don't include activities that took less than 10 uninterrupted minutes.

WALK?

❍ none	❍ 1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days

How much time did you usually spend during breaks at school on **one** of those days **walking**?

_____**hours** _____**minutes per day**

VIGOROUS physical activity, that takes hard physical effort and makes you breathe much harder than normal, like running?

❍ none	❍ 1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days

How much time did you usually spend during breaks at school on **one** of those days doing **vigorous physical activities**?

_____**hours** _____**minutes per day**

MODERATE physical activity, that takes moderate physical effort and makes you breathe somewhat harder than normal, like dancing?

❍ none	❍ 1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days

How much time did you usually spend during breaks at school on **one** of those days doing **moderate physical activities?**

___**hours** ___**minutes per day**

Housework and Gardening

This part is about physical activity that you might have been done during the last 7 days in and around the house.

13. During the last 7 days, on how many days did you do, for at least 10 uninterrupted minutes, physical activities in the garden or at home that took at least moderate physical effort and made you breathe somewhat or much harder than normal like carrying heavy loads, scrubbing floors or sweeping. Don't include activities that took less than 10 uninterrupted minutes.

❍ none	❍ 1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days	❍ 6 days	❍ 7 days

How much time did you usually spend on those activities in the home and yard on such a day?

___hours ___minutes <u>per day</u>

Transport Physical Activity

These questions are about how you travelled from place to place during the last 7 days. It includes places like school, the shops, the cinema, and so on.

14. During the **last 7 days**, on how many days did you **travel for at least 10 uninterrupted minutes ...** Don't include activities that took less than 10 uninterrupted minutes.

... **IN A MOTOR VEHICLE** like a train, bus or car?

❍none	❍1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days	❍ 6 days	❍7 days

How much time did you usually spend <u>on **one** of those days</u> **travelling by motor vehicles?**

___hours ___minutes <u>per day</u>

... **WITH A BICYCLE ?**

❍none	❍1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days	❍ 6 days	❍ 7 days

How much time did you usually spend <u>on **one** of those days</u> **cycling** from place to place?

___hours ___minutes <u>per day</u>

... **BY FOOT?**

❍none	❍1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days	❍ 6 days	❍7 days

How much time did you usually spend walking from place to place on <u>**one** of those days</u>

___hours ___minutes <u>per day</u>

Recreation, Sport and Leisure-time Physical Activity

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned!!!

15. During the last 7 days on how many days did you do one of the following **for at least 10 uninterrupted minutes in your leisure time**? Don't include activities that took less than 10 uninterrupted minutes!

WALK?

❍none	❍1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days	❍ 6 days	❍7 days

How much time did you usually spend on **one** of those days **walking** in your leisure time?

_____hours _____minutes per day

MODERATE physical activity, that takes moderate physical effort and makes you breathe somewhat harder than normal, like dancing?

❍none	❍1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days	❍ 6 days	❍7 days

How much time did you usually spend on **one** of those days doing **moderate physical activity** in your leisure time?

_____hours _____minutes per day

VIGOROUS physical activity, that takes hard physical effort and makes you breathe much harder than normal, like running?

❍none	❍1 day	❍ 2 days	❍ 3 days	❍ 4 days	❍ 5 days	❍ 6 days	❍7 days

How much time did you usually spend on **one** of those days doing **vigorous physical activity** in your leisure time?

_____hours _____minutes per day

Questions about promoting walking and cycling in Kilkenny

16. Have you ever heard of a campaign to promote walking or cycling?

Yes ❑

No ❑ → You're finished

I don't know ❑ → You're finished

17. What was it called?

____

____

Thanks for your help!

APPENDIX E

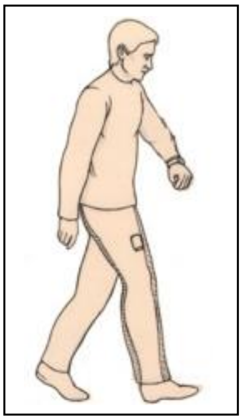
Method of calculating distance travelled to school

1. Go into Google Maps (https://maps.google.ie/)
2. Select Carlow
3. Click on 'Get Directions'
4. Select the Walking Icon (underneath the 'Get Directions' icon there is a car and a walking icon)
5. Put in the address from the survey into A
6. Into B put:
7. For St Leo's School, input/select 'St. Leo's College, Old Dublin Road, Carlow'
8. For the CBS School, input/select 'CBS, station road, carlow'
9. Click on 'Get Directions'**Note:**
10. Record the distance travelled
11. Take a screenshot of the screen and save

APPENDIX F

Information on ActivPAL

ActivPAL Accelerometer



This is the **ActivPAL** accelerometer and it is a tiny, lightweight gadget that measures the activity that you do during your normal day. It can tell how long you spend lying, sitting, standing and walking.

The accelerometer is worn on the mid part of the front of you **right** thigh and is held on by an adhesive pad (stickie). This is skin and hair friendly and can be removed and repositioned on the skin on multiple occasions.

What do I have to do?

The accelerometer will be attached to your right thigh using a stickie and a standard support bandage. Remove the plastic layer from the stickie and attach it firmly to the back of the ActivPAL. Then, remove the butterfly tabs and apply the ActivPAL firmly to the skin. Pull the support bandage over the ActivPAL. If the ActivPAL comes loose, the bandage will then catch it. You can take part in all activities **(except water based activities)** as normal wearing the ActivPAL.

We ask that you leave the accelerometer on **all day and all night** except when you are bathing, swimming or doing any other water based activities. When showering, remove the support bandage, ActivPAL and adhesive pad, and leave them in a dry, safe place. Try not to use any moisturising or other creams on the area where the ActivPAL will be worn, as this can make the stickie less stickie! Once you are dried off, reattach the ActivPAL using the same stickie. **Please record on your ActivPAL log sheet the day and times that you took the ActivPAL off and put it back on.**

You should replace the adhesive pad every 2-3 days. There are three adhesive pads included in your pack, which should be enough for wearing the ActivPAL for a full week. However, if you run out, or need more, please phone Niamh and she will deliver more to you. Arrangements will be made with you at the end of the study period to collect the ActivPAL.

Frequently Asked Questions

Where should I apply the ActivPAL?

It is most comfortable to wear the ActivPAL on the mid line of the right thigh, about half way down between the hip and the knee.

What if it is not secure?

Ensure that you have the correct side sticking to your leg. The butterfly tab side will stick to your leg while the clear plastic side will stick to the ActivPAL. The “stickie” will not work it any moisturisers or creams are on the thigh. If the adhesive pad comes loose after a day or so, you may need to replace it. Add the support bandage over the ActivPAL for extra support.

When should I remove the ActivPAL?

The ActivPAL can be worn comfortably all day and all night and should not impede normal activities. It MUST be removed before bathing and swimming or before any other activities which may mean the ActivPAL could come into contact with water.

How do I know the ActivPAL is working?

The ActivPAL is a continuous recorder so will never stop recording. But you can be sure by checking the little light in the front panel. The light will flash green every six seconds. If it is not flashing green please phone Niamh immediately!

What if I lose the ActivPAL?

Don’t panic. If you lose or misplace the ActivPAL, please phone Niamh IMMEDIATELY. She will then try to retrace your steps with you, and will help you look for (and hopefully find) the ActivPAL. ActivPAL’s are not cheap so it is very important that you contact Niamh as soon as you have misplaced the device!

What if I experience difficulty or have a question?

At any stage, day or night, if you are having a problem with the device or have a question please give us a ring or text. No matter how small or silly you think the question is it could turn out to be very important later on.

Niamh’s Mobile Number: 087-2079178

APPENDIX G

Informed Consent Sheet

Waterford Institute *of* Technology

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE *of* TECHNOLOGY CARLOW
At the Heart of South Leinster

Information and Informed Consent for the Physical Activity and Active Transport Research Study

Dear Student,

You have already received some information about the survey on active travel I am doing in your school. , A small number of students have been selected to wear a little gadget called an accelerometer which is similar to a pedometer. You have been selected to participate in this extra part of the study. I need your permission to do this, so here's some more information to help you decide whether you want to participate or not:

What is the research for?
To measure the physical activity of teenagers, recorded by questionnaire and by wearing an ActivPAL (accelerometer).

What will happen if I decide to participate?
If you decide to participate you will be asked to wear an ActivPAL on your thigh for a period of 7 days in September before completing the questionnaire in school.

How will my information be used?
Waterford Institute of Technology will protect all the information about you. Your identity or personal information will not be revealed, published or used in future studies. The study findings will be presented in a postgraduate thesis, academic publications, conference papers and other scientific publications.

What do I need to do now?

a) If you are happy to participate then please sign the attached document
b) If you are not happy to participate, then you have nothing to do.

Thanks for taking the time to read this and please don't hesitate to contact me if you have any further questions.

Niamh Spratt
059-9175571
E: niamh.spratt@gmail.com

Informed consent for 'measuring physical activity' project

Questions for you to consider:

1. I confirm that I have read the study information provided
2. I have been given the opportunity to ask questions of the researcher.
3. I understand that my participation is voluntary and I am free to withdraw at any time without giving a reason and without consequence.

I consent to take part in this research project to compare physical levels recorded by questionnaire and an ActivPAL.

Your name (PRINT): ______________________________________

Your name (signature): ______________________________________

Date: ______________________________________

APPENDIX H

Parental Information Letter

Waterford Institute *of* Technology

Information about the Physical Activity and Active Transport Research Study

Dear Parent / Guardian,

I am currently completing a Research Masters on Physical Activity and Active Transport in Adolescents in Carlow and Kilkenny. In order to complete the research, I am recruiting participants from both a boy's and a girl's school in the Carlow and Kilkenny Region. The research itself will consist of the following:

1. A questionnaire to be completed by all second years and transition years
2. A sample of approximately 20 second years and 20 transition years to wear a small non-obtrusive portable device called an ActivPAL accelerometer for 7 days. The accelerometer measures the time a person spends walking, sitting, lying.

I would greatly appreciate your child's participation in this project. I have attempted to outline below some answers to further questions you may have.

What is the research for?
To compare the physical activity levels of teenagers in Carlow and Kilkenny recorded by questionnaire and by wearing an ActivPAL.

What will happen if I allow my child to participate?
There are two parts to the study; the first part is the physical activity questionnaire which will be completed by ALL consenting students and takes about 10 – 15 mins to fill out. For the second part of the study, a sample of 20 students will be randomly selected to wear an ActivPAL accelerometer on their thigh for a period of 7 days in September/October before they complete the questionnaire in school.

How will my child's information be used?
Waterford Institute of Technology will protect all the information about your child. Your child will remain anonymous and their identity will not be revealed at any stage. The study findings will be presented in a postgraduate thesis, academic publications, conference papers and other scientific publications.

What do I need to do now?
There are two options available to you and your child which are outlined overleaf:

Option 1

If you **do not wish** your child to participate in **ANY** part of this research project – please sign below and return to the school.

I **do not wish** my child to participate in the Phyisical Activity and Active Transport Research Study.

Students Name: ________________________________

Your Name: ____________________________________Signature: _________________________

Date: ____

Option 2

If you are happy for your child to participate in both the **Questionnaire** and **Accelerometer** part of the study then you **do not have to do anything**.

If your child is selected to wear the accelerometer, they will be given additional information to share with you before participating.

Please note that participation in the study is completely voluntary and participants are free to withdraw at any time without giving a reason and without consequence.

Thanks for taking the time to read this and please don't hesitate to contact me if you have any further questions.

Niamh Spratt
Tel: 059 9175571 / Email: niamh.spratt@gmail.com

APPENDIX I: IPAQ-A Self-Report Data on PA Domains and Intensities Weekly

Physical Activity (PA) (min/week) per domain and per intensity for groups based on gender and age (B = boys, G = girls)

			School-Based PA	Home-Based PA (Housework / Gardening)	Transport-Related PA	Leisure-Time PA	Walking	Moderate PA	Vigorous PA	Total PA
Gender	Boys	n	102	90	95	72	96	104	87	105
		Mean	268.65	231.61	567.04	245.56	617.4	468.94	135.13	1140.91
		SD	182.1	325.44	1478.9	155.67	1458.95	472.98	109.13	1564.66
		Median	265.0	120.00	225.0	262.5	345	320	150	940
	Girls	n	214	188	199	164	198	216	192	218
		Mean	235.64	173.75	250.17	205.39	351.74	342.07	119.94	764.03
		SD	179.74	260.86	373.48	158.88	375.14	339.05	112.39	598.13
		Median	217.5	87.5	100.00	180.00	230	217.5	90	672.5
Age (years)	13-14	n	193	162	173	140	174	194	165	196
		Mean	237.23	220.49	364.93	205.14	426.89	400.27	129.85	884.47
		SD	183.59	315.58	1136.56	163.22	1121.2	420.3	114.76	1246.62
		Median	205	95	75	180	205	272.5	120	677.5
	15-16	n	123	116	121	96	120	126	114	127
		Mean	260.52	153.36	334.88	235.89	455.3	357.18	117.18	889.76
		SD	176.31	228.73	381	150.74	377.55	342.36	106.42	558.21
		Median	255	72.5	180	240	330	275	104.5	870

Gender & Age			School-Based PA	Home-Based PA (Housework / Gardening)	Transport-Related PA	Leisure-Time PA	Walking	Moderate PA	Vigorous PA	Total PA
	B 13-14	n	63	54	82	44	58	64	51	65
		Mean	242.65	241.39	676.95	214.09	672.84	473.49	133.25	1182.05
		SD	159.19	341.13	1892.63	151.83	1856.05	481.33	110.12	1941.7
		Median	210	95	240	210	300	300	140	835
	B 15-16	n	39	36	39	28	38	41	36	41
		Mean	310.64	216.94	409.23	295	532.76	461.95	137.78	1076.71
		SD	209.34	304.55	427.10	151.2	382.01	465.70	109.21	648.26
		Median	315	120	210	320	435	340	165	1000
	G 13-14	n	130	108	117	96	116	131	114	132
		Mean	234.6	210.04	215.59	201.03	303.91	365.05	128.33	740.19
		SD	194.84	303.12	384.06	168.8	371.29	384.61	117.22	660.25
		Median	202.5	97.5	60	180	162.5	220	120	562.5
	G 15-16	n	84	80	56	68	82	85	78	86
		Mean	237.25	124.75	299.51	211.54	419.4	306.64	107.68	800.63
		SD	154.59	179.99	354.33	144.71	372.33	251.4	104.45	489.13
		Median	250	225	165	205	300	215	90	755