Objective Assessment and Modification of Physical Activity and Health Indices in Adolescent Females

A thesis submitted to the University of Limerick in fulfilment of the requirements for the Degree of Doctor of Philosophy

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ABSTRACT

The initial aim of this research was to develop and validate a protocol for the objective measurement of physical activity for use with adolescents. A secondary aim was to engage groups of adolescent females in a physical activity intervention which would increase physical activity levels and improve health parameters.

Before physical activity could be objectively measured the physical activity measurement system needed to be validated and piloted. The ActivPAL accelerometer was used as the measure of free-living physical activity. Lab based validation of the accelerometer indicated that the device underestimated energy expenditure in certain free-living activities and at higher intensities which is a common problem for accelerometers. It did provide a good measure of moderate to vigorous physical activity and a direct measure of sedentary activity.

Three physical activity interventions were undertaken in a Secondary school setting. Intervention one was a short after school intervention which was seen as a pilot due to methodological problems. Low self-reported physical activity and unfavourable body composition data did confirm the need for more robust, longer interventions. Intervention two took place within a transition year programme and intervention participants significantly increased their moderate to vigorous physical activity and cardiovascular fitness. Intervention three observed no significant improvements in physical activity, cardiovascular fitness or body composition in the intervention group that were independent of the control group. However, these parameters improved in both the control and intervention groups. It is hypothesised that the impact of such interventions in the long term may be more successful in increasing physical activity. Exposing adolescent females to a physical activity intervention using novel and non-competitive activities may still be a cost friendly supplement to physical education for.

To quantify physical activity and sedentary levels in the general population of 15-17 year old females, a random cross-sectional sample from the local city were chosen for the Limerick Physical Activity Study. A full 7 day accelerometry protocol was used following best practice recommendations. Detailed analysis of sedentary data revealed that this cohort of adolescent females accumulated more bouts of sedentary activity and of longer duration during school days compared to weekend days.

In summary, the ActivPAL accelerometer was found to be an acceptable measure of objective physical activity in adolescent females and provided data of great depth and quality. Objectively measured sedentary levels were high and were measured without the use of thresholds, a unique feature of this research. When measured using accelerometry, the majority of these adolescent females did not meet physical activity recommendations and their physical activity was below levels reported from previous Irish studies based on self-report.
Declaration

Objective Assessment and Modification
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in Adolescent Females

“I hereby declare that this is entirely my own work and has not been submitted to any other university or higher education institution, or for any academic award in this University. Where use has been made of the work of other people, it has been fully acknowledged and referenced.”

Signed: ______________________

Date: ______________________
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For Daddy
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Chapter One

Introduction
1.1 Introduction

The national and international media are reporting with increased frequency about the development of a childhood ‘obesity epidemic’ linked to a reduction in children’s physical activity levels. The Irish media has claimed that childhood obesity is nearing an ‘epidemic’ (RTE News, 2008; Shanahan, 2009) and this echoes the World Health Organisation’s (WHO) ‘obesity epidemic’ (WHO, 1998). The rise in obesity levels coincide with a greater reliance on technology and automated labour which has been associated with lower physical activity levels in children (Esliger et al., 2010). In an Irish context, two large scale qualitative studies (Kelleher et al., 2003; 1999) have shown that self reported physical activity levels have decreased over a number of years with adolescent female self reporting the lowest physical activity levels. Adolescent females are also highlighted as an ‘at risk’ population. Claims include that adolescent girls are not engaging in enough, or any at all, moderate to vigorous physical activity, are not partaking in school physical education classes, are involved in sedentary behaviours and are not actively commuting to school.

1.2 Rationale for the Study

The rationale for intervening to increase physical activity during adolescence is well documented. Adolescence represents a critical period in the development of obesity (Dietz, 2004) and it is when the physical activity and nutritional habits that abound in adulthood become consolidated (Kelder et al., 1994). Before physical activity interventions can be undertaken a valid and reliable method to measure physical activity needs to be decided upon. Since objective measurement of physical activity has not been employed in the Republic of Ireland to assess physical activity levels the method decided upon needs to be validated and calibrated where necessary.

This thesis considers the adolescent physical activity and health relationship and ways to modify and measure this relationship. Chapter 2 presents a breadth of literature ranging from physical activity levels and its benefits, obesity levels and associated risks and methods of measuring both parameters. Evidence on the issues surrounding the objective measurement of physical activity, namely accelerometry, will be dealt with. An
overview of physical activity interventions in adolescent females will also be presented. The methodologies developed and employed will be described in detail in Chapter 3. The remaining chapters are organised as follows. Chapter 4 describes the testing of the inbuilt equation in the ActivPAL which estimates energy expenditure and also tests the functionality of the step rate measure. Chapter 5 develops on the previous chapter and describes the development and cross-validation of a new prediction equation for use with the ActivPAL Physical Activity Logger in adults. It also discusses the limitations of such new equation and recommends future work that should be undertaken to further the utility of the ActivPAL. The development of accelerometry thresholds for physical activity interpretation is also described. Chapters 6 and 7 describe three school-based physical activity interventions that were used in adolescent female populations. The ActivPAL was used in these interventions as an objective measure of free living physical activity. Chapter 8 describes a cross-sectional study of physical activity and sedentary levels of adolescent females in the local area using an accelerometry best practice protocol. Their sedentary levels and patterns are investigated using ActivPAL output and specially designed programmes for efficient data reduction. As well as sedentary levels being described, the interaction between physical activity, sedentary levels and health outcomes are considered. The final chapter sees all results discussed and critically appraises the research undertaken during this Ph.D.

1.3 Aims and Hypotheses

The aims of this Ph.D. were:

• To validate an objective measure of physical activity for use with females and to calibrate it’s outputs to estimate energy expenditure.

• To use this objective measure of physical activity to measure the free-living physical activity levels of groups of adolescent females.

• To develop protocols to follow when using this objective measure of physical activity. This would include ways to increase compliance and to interpret, reduce and report the wealth of collected data.

• To engage groups of adolescent females in physical activity interventions which aimed to increase physical activity and improve health parameters.
• To measure the sedentary levels and patterns of a random cross-section of adolescent females and compare these results to international and subjective Irish data.

The hypotheses of this Ph.D (stated as the null hypothesis):

• Ho1= METs estimated using the ActivPAL equation will differ significantly from METs measured by indirect calorimetry.
• Ho2= Step rate measured by the ActivPAL will differ significantly from step rate measured by video recorder and by the Actigraph.
• Ho3= An equation based on treadmill data will not accurately estimate energy expenditure in adolescent and young adult females.
• Ho4= An equation developed from young female adult data will underestimate when cross-validated on free-living activities and when applied to free-living monitoring.
• Ho5= A physical activity intervention will not increase participants levels of MVPA.
• Ho6= A physical activity intervention will not positively change participants health parameters.
• Ho7= Sedentary levels are not significantly related to health parameters independent of physical activity levels.
• Ho8= There is no significant difference in sedentary levels and patterns and physical activity between weekdays and weekend days.
Chapter 2

Literature Review
2.1 Introduction

The following literature review describes the benefits of being physically active in childhood and adulthood and also the dangers that accompany inactivity. The benefits of being physically active as a young person can affect future health and future physical activity levels and this link will be considered as a rationale for promoting physical activity in adolescence. The negative consequences of obesity in childhood and adulthood are also considered. The relationship between childhood and adolescent body composition will be considered and it will be discussed how obesity tracks strongly from adolescence into adulthood meaning the current burden of obesity will affect future health. Like the tracking of physical activity, this link will be considered as a rationale for getting adolescents to be physically active. Irish and international data on physical activity and body composition will also be presented and critically appraised. Measurement of physical activity will also be discussed with a focus on accelerometry. Interventions that are school based will be discussed at the end of the chapter.

2.2 Physical Activity and Health

Physical inactivity is a risk factor for a number of diseases including cardiovascular disease (Kannel & Sorlie, 1979), coronary episodes (Lee et al., 2001; Paffenbarger et al., 1978), hypertension (Chobanian et al., 2003), obesity (Haapanen et al., 1997) and its associated co-morbidities, Type II diabetes (Rana et al., 2007; Hu et al., 2001) and colon (Meyerhardt et al., 2009; Wolin et al., 2009) and other cancers (Bouchard et al., 1994). Higher physical activity has been related to increased longevity (Paffenbarger et al., 1986), a more favourable mental state (Zoeller, 2007) and a decrease in all cause mortality (Slattery et al., 1989). Powell et al. (1987) provides an excellent and in-depth review of early studies to investigate physical activity levels to CHD and confirms that the risk of CHD is inversely related to physical activity levels. The WHO Global Strategy on Diet and Physical Activity (2004) reports that physical activity reduces blood pressure, improves high density lipoprotein (HDL) cholesterol levels, improves control of blood glucose in overweight people, even without significant weight loss, and reduces the risk for colon cancer and breast cancer among women (WHO, 2004).
2.2.1 Adult Physical Activity and Health

Evidence has been accumulating for many decades as to the extent of the connection between physical activity and disease states (Blair & Morris, 2009). As well as the connections mentioned in section 2.2, physical activity has a positive effect on body mass and body fat levels (Murphy et al., 2006), HDL and low density lipoprotein (LDL) concentrations (Brownell et al., 1982) and on the risk of metabolic syndrome (Simmons et al., 2008). It has been suggested that higher levels of physical activity can lessen the impact of overweight and obesity on morbidity (Blair & Brodney, 1999) and reduce the risk of Type II diabetes especially in obese patients (Hu et al., 2001). However, more recent analyses indicated that both obesity and physical inactivity were independent contributors to the development of Type II diabetes (Rana et al., 2007) so being physically active did not abolish the excess risk associated with obesity (Sullivan et al., 2005; Weinstein et al., 2004).

Preventing and delaying the onset of Type II diabetes mellitus has been shown to be possible with lifestyle changes including an increase in physical activity (Diabetes Prevention Program Research Group, 2002; Tuomilheto et al., 2001) compared to a typical drug or a placebo after 2.8 years follow up. This was in those aged 25 and over who were at risk of developing Type II diabetes. The intensive lifestyle guidance used included dietary and physical activity changes so the individual effects of each of these would need to be investigated further.

The effect of intensity of the physical activity needed for health benefits has also been debated. Sesso et al. (2000) found that a reduced risk of CHD was only evident in relation to total and vigorous physical activity in male Harvard alumni. While light and moderate physical activity did not have the same association the authors accept that this type of activity is harder to measure and other studies have shown the beneficial effects of moderate activity in men (Paffenbarger et al., 1993; Slattery et al., 1989).
2.2.2 Adolescent Physical Activity and Health

In adults, the relationships between physical activity and health are well established and
have been outlined. The relationship between child and adolescent physical activity and
health are less well understood but it is often assumed that physical activity undertaken in
childhood and adolescence will be beneficial to health during adulthood. The two main
questions that have been asked are (Biddle et al., 2004):

(i) Does physical activity in adolescence affect adolescent health?
(ii) Does physical activity in adolescence affect adult health?

Blair et al. (1989) previously proposed a model of the pathways that physical activity in
youth can affect adult health:

(i) Affecting current youth health which would in turn affect adult health;
(ii) Directly affecting future health;
(iii) Affecting adult physical activity which in turn would affect adult health.

All of these concepts will be discussed in the following three sections.

2.2.3 Adolescent Physical Activity as an Indicator of Current Health Risk

Relationships between physical activity and childhood and adolescent health have been
found to be weakly related (Eisenmann, 2004). This is because diseases often do not
manifest themselves until later years. However, some precursors of obesity, type II
diabetes and cardiovascular disease are evident in children and adolescence (Newman et
al., 1986). Physical activity in adolescence has been inversely associated with a number of
cardiovascular disease risk factors including elevated blood lipids (Armstrong & Simons-
Morton, 1994), hypertension (Alpert & Wilmore, 1994) and obesity (Bar-Or &
Baranowski, 1994). Physical activity is positively associated with physical fitness (Twisk et
al., 2000), CVD risk factors (Andersen et al., 2006), bone mass (Welten et al., 1995), and
psychological well-being.
Low levels of physical activity have been identified as a possible modifier associated with metabolic syndrome risk factors in children and youth (Ekelund et al., 2009b; Ekelund et al., 2006a). Ekelund et al. (2004) found that 9 to 10 year olds who spent more than 2 hours in MVPA per day had significantly lower sum of 5 skinfolds than children who spent less than one hour in MVPA. Treuth et al. (2007) reported that adolescents spent most of their waking hours in light and sedentary activities with the amount of time spent in MVPA being slightly lower in overweight rather than normal weight females. Numerous other studies have found relationships of varying magnitude between physical and a more favourable body composition (Patrick et al., 2004; Riddoch et al., 2009; Trost et al., 2008). Conversely, Barbeau et al. (2007) did not find a significant relationship between physical activity levels and current levels of adiposity. Results from the Québec Family Study found a relationship between physical activity and CHD risk factors but physical fitness exhibited a slightly stronger relationship than physical activity levels (Katzmarzyk et al., 1999). This link between physical fitness and health will be discussed in section 2.5.2. It is erroneous to assume that all overweight or obese adolescents do no physical activity. It is also incorrect to assume that all adolescents who partake in no physical activity are overweight or obese but the link between the two is strong. The direction of the activity-obesity relationship is less well researched. It is unclear if overweight people do not partake in physical activity because they are overweight or are they overweight because they do not partake in sufficient levels of physical activity.

### 2.2.4 Adolescent Physical Activity as an Indicator of Future Health Risk

Establishing a clear connection between childhood physical activity and health problems in later life is difficult as it may take many years for health problems to manifest themselves (Biddle et al., 2004). For example, the beneficial effects of physical activity in childhood and adolescence in preventing cardiovascular disease (CVD) have often been disputed (Twisk et al., 2000) since children are normally not prone to CVD. Atherosclerosis is a disease that has its origins in childhood with endothelial dysfunction being its earliest detectable manifestation (Watts et al., 2004b). Studies have found that 8 weeks of exercise training in obese children and adolescents did improve this proxy measure of atherosclerosis (Watts et al., 2004a). It has also been shown that physical
activity in childhood and adolescence can have an effect on certain health parameters in adulthood and thus reduce the risk of coronary heart disease (Schofield et al., 2007). Conversely, adolescent physical activity was not a predictor of adult CVD risk profile (Boreham et al., 2002; Twisk et al., 2002).

2.2.5 Adolescent Physical Activity as a Predictor of Adult Physical Activity

How physical activity in childhood and adolescence relates to physical activity in adulthood is a concept known as tracking. Tracking refers to the prediction of future values based on earlier values (Ware & Wu, 1981), stability of a health behaviour over time (Kelder et al., 1994) or the maintenance of a relative position of rank in behaviour over time (Malina, 2001). Like the tracking relationship of obesity which will be discussed in section 2.3.2 tracking can also be applied to physical activity behaviours, patterns and lifestyle choices. That is to say, youths identified as having high physical activity levels will also have high levels in relation to their reference group in adulthood. The other definition of tracking is that a youth who participates in 150 minutes of MVPA per week will also do 150 minutes of MVPA in adulthood. Habits that are formed in these formative years continue into adulthood (Kelder et al., 1994).

Evidence has shown that physical activity scores (high v low) track through adolescence (Kelder et al., 1994) and physical activity habits that are adopted in adolescence are followed for many years (Anderssen et al., 2005; Berkey et al., 2000; Twisk, et al., 2000). 6149 adolescents were followed over one year by Berkey et al. (2000) and they found that year to year inactivity and activity levels were more stable in the older (14-16 year olds) girls than the younger girls. This illustrates how regular physical activity habits were already established by age 14 to 16. Physical inactivity and sedentary behaviours track better from adolescence into adulthood than physical activity (Anderssen et al., 2005; Matton et al., 2006). Anderssen et al. (2005) looked at physical activity patterns from ages 13 to 21 in 927 Norwegian adolescents and found that only 25% of those classified as frequently active at baseline were still the most active 8 years later. This is a finding which does not provide adequate support to the notion that promoting high levels of physical activity in adolescence will mean high levels of physical activity in adulthood. Compared
with adults, obesity treatment and prevention through physical activity may have a
greater effect on the younger adolescent as their behaviour is less fixed or consolidated
(Koletzko et al., 2002). Preventative strategies should start as early in life as possible to
increase activity and reduce inactivity (Berkey et al., 2000).

2.2.6 Irish Data on Physical Activity Levels

Five large scale representative studies have reported on the physical activity levels of the
Irish population. The Slán studies of 1999 (Kelleher et al., 1999), 2003 (Kelleher et al.,
2003) and 2008 (Morgan et al., 2008) and the Irish Sports Monitor (Lunn et al., 2007)
study have reported on adult and children physical activity levels. A soon to be released
study called the Children’s Sports Participation and Physical Activity Study has also
collected physical activity data from children, including accelerometry. The Slán studies
allow monitoring of physical activity levels over many years. The most recent Slán study
(Morgan et al., 2008) reported International Physical Activity Questionnaire Scores while
the earlier two asked simpler questions about frequency and the authors felt this was
comparable. The levels of inactivity are presented in Figure 2.1. The percentage of
respondents who reported moderate and/or vigorous activity 3 or more times per week
for at least 20 minutes were similar 38%, 40% and 41% in 1998, 2002 and 2007
respectively (Morgan et al., 2008). A study by Livingstone et al. (2008), entitled Physical
Activity Patterns in a Nationally Representative Sample of Adults in Ireland (N=1379 18-
64 year olds), found that time spent in recreational activities was low but high amounts of
walking for activity and vigorous activity were self-reported.

Such data on physical activity levels are hampered by the nature of the data collection in
that they have used self report methods. The limitations of self report are discussed fully
in section 2.7.2.3. Notwithstanding, self reported physical activity data provides Irish
evidence that is comparable to international studies and, due to it’s underestimative
nature, may provide an even more sobering picture of physical activity and sport in
Ireland. Studies reporting physical activity data of Irish children are tabulated in Table
2.1.
The School Children and Sport in Ireland report (Fahey et al., 2005) and the results of the TAKE PART study (Woods et al., 2004) lend support to the claim that females partake in less physical activity than their male counterparts. The Slán results also support international findings that physical activity levels decrease with age in a female population especially with 55% of 10-11 year old girls to only 25% of 15-17 year old girls reporting being physically active four or more times per week. The Health Behaviours of SchoolAge Children (HBSC) arm of Slán 2003 (Kelleher et al., 2003) reported that approximately 21% of girls aged 15-17 years of age engage in no vigorous activity weekly. This is an increase from approximately 17% in the 1998 HBSC study. In the same survey from 2003 survey, 8% of 12-14 year old girls reported that they do not engage in any vigorous physical activity weekly. This illustrates how participation in physical activity declines with age especially in late adolescence. Again the fact that this is based on self reported data should lead to caution when interpreting these results.
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Population</th>
<th>Findings</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting the International Adolescent Physical Activity Guidelines:</td>
<td>Shiely and MacDonncha (2009)</td>
<td>N=28 12-15 year olds</td>
<td>11% using self report and 0% using HR monitoring met MVPA guidelines</td>
<td>Self report and HR Monitoring</td>
</tr>
<tr>
<td>A Comparison of Objectively Measured and Self-reported Physical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity Levels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relationship Between Physical Activity, Inactivity, Cardiorespiratory</td>
<td>Hussey et al. (2007)</td>
<td>N=224 7-9 year olds in Dublin</td>
<td>Boys spent 64 mins and girls 37 mins at hard/vigorous per day</td>
<td>Parental questionnaire</td>
</tr>
<tr>
<td>Fitness and Body Composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Physical Activity Levels of Children Aged 7–9 Years</td>
<td>Belton &amp; MacDonncha (2007)</td>
<td>N=87 7-9 year olds</td>
<td>30% engaged in 30mins MVPA</td>
<td>4 day HR Monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School Children and Sport in Ireland</td>
<td>Fahey et al. (2005) for the ESRI and Irish</td>
<td>N=7360 primary and</td>
<td>46% 4 or more times per week, further 26% 3 times per week</td>
<td>Self report non-school and extra curricular</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>secondary school</td>
<td></td>
<td>sport participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAKET PART</td>
<td>Woods et al. (2004)</td>
<td>N= 1508 15-17 year olds in Dublin</td>
<td>52% of boys and 62% of girls ‘not regularly active’</td>
<td>Self reported questionnaire</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slán/HBSC 2002</td>
<td>Kelleher et al. (2003)</td>
<td>N=5712 School Aged</td>
<td>42% boys and 62% girls not exercising 4 or more times per week</td>
<td>Self reported frequency of getting ‘out of breath or sweat’</td>
</tr>
<tr>
<td>Children</td>
<td></td>
<td>Children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slán 1998</td>
<td>Friel et al. (1999)</td>
<td>School Aged Children</td>
<td>55% girls not exercising 4 or more times per week</td>
<td>Self reported frequency of getting ‘out of breath or sweat’</td>
</tr>
<tr>
<td>Physical Activity Patterns of Northern Irish Schoolchildren</td>
<td>Riddoch et al. (1991)</td>
<td>N=45 11-16 years old</td>
<td>Boys engaged in more VPA, older children had lower PA</td>
<td>Heart rate monitoring of up to 4 school days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.2.7 International Data on Physical Activity Levels

Physical inactivity is now being called a great risk to health of the 21st century (Blair, 2009; Blair & Morris, 2009) and this is based on years of data relating physical inactivity to disease states. The World Health Organisation (WHO, 2002) estimates that physical inactivity among adults is 17%, ranging from 11% to 24% across countries. Comparisons of physical activity levels between countries are confounded by a number of factors most notably the measurement of physical activity used. Large scale studies have relied on self report measures but large scale studies from the United States, such as the National Health and Nutrition Examination Survey (NHANES), now use accelerometry as part of their physical activity monitoring.

One survey which used similar methodologies across 32 countries is the Health Behaviour in School-Aged Children (HBSC) Study which investigated physical activity levels of young people across all socioeconomic classes. The mean number of days that participants achieved the goal of 60 minutes of MVPA differed among countries, genders and age groups but ranged from a low of 3.09 days (France) to a high of 4.40 days (Ireland). That is to say that no country achieved the desired 5 days per week (Table 2.2). The Scottish Health Survey reported that 56% of girls and 72% of boys aged 2-15 met recommendations using self report (Scottish Physical Activity Review Group, 2010).

<table>
<thead>
<tr>
<th>Age</th>
<th>11 years</th>
<th>13 years</th>
<th>15 years</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>5.02 (1.94)</td>
<td>5.07 (1.93)</td>
<td>4.44 (1.80)</td>
<td>4.88 (1.92)</td>
</tr>
<tr>
<td>Girls</td>
<td>4.61 (1.99)</td>
<td>4.27 (1.97)</td>
<td>3.39 (1.99)</td>
<td>4.05 (2.05)</td>
</tr>
</tbody>
</table>

N= 1255 boys and n=1543 girls

Objectively measured physical activity levels of American youths in the NHANES study (Troiano et al., 2008) showed that males were more physically active than females at every age classification. Other international studies have reported the same (Basterfield et al., 2008; Borraccino et al., 2009; Ekelund et al., 2004; Scottish Physical Activity Review Group, 2010).
MVPA declined throughout from childhood and adolescence and into early adulthood for both sexes.

**Table 2.3 Mean minutes per day at moderate to vigorous physical activity for total activity and in modified bouts of 10 minutes or more measured by accelerometry (Troiano et al., 2008)**

<table>
<thead>
<tr>
<th>Age</th>
<th>Males Overall</th>
<th>Males Modified</th>
<th>Females Overall</th>
<th>Females Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-11</td>
<td>95.4</td>
<td>45.1</td>
<td>75.2</td>
<td>26.2</td>
</tr>
<tr>
<td>12-15</td>
<td>45.3</td>
<td>18.6</td>
<td>24.6</td>
<td>7.1</td>
</tr>
<tr>
<td>16-19</td>
<td>32.7</td>
<td>10.9</td>
<td>19.6</td>
<td>5.5</td>
</tr>
</tbody>
</table>

### 2.3 Body Composition and Health

The evidence relating body composition to health parameters and to current and future risks have been well researched and reviewed. The Centers for Disease Control and Prevention and the WHO have both highlighted overweight and obesity as being a risk factor for a number of different diseases. The WHO global strategy on diet and physical activity cites obesity as a risk of diseases including Type II diabetes, cardiovascular disease, hypertension and stroke, and certain forms of cancer (WHO, 2004) and this is backed up by and based on literature.

Risks related to obesity include cardiovascular disease (Rashid *et al*., 2003), coronary heart disease (Weinstein *et al*., 2008), Type II diabetes (Finucane *et al*., 2008), sleep apnea, certain cancers, depression, psychosocial problems. Recent analyses indicated that both obesity and physical activity were independent contributors to the development of Type II diabetes (Rana *et al*., 2007) and all-cause mortality (Hu *et al*., 2001). The former studies findings are in line with the Finnish Diabetes Prevention Study (Lindström *et al*., 2003) and the Diabetes Prevention Program study (Hamman *et al*., 2006) that found that even modest weight loss led to substantial reduction in diabetes risk. Increases in skinfold assessed obesity levels in youth are associated with an increase/clustering or CVD risk factors (Freedman *et al*., 1985).
It is difficult to assess the effect an adverse body composition in youth has on health since problems relating to that usually only manifest themselves in later years. However, evidence has shown that some precursors to CVD such as endothelial dysfunction (Celermajer et al., 1992), abnormal lipid levels (Centers for Disease Control and Prevention, 2010), fatty streaks and vascular lesions are evident in youth and young adults and BMI is positively related to this (Berenson et al., 1998; Freedman et al., 1999). The metabolic syndrome and its risk factors are also related to adverse body composition in adolescents (Cook et al., 2003).

Measurements of body mass, body mass index (BMI) and percentage body fat are very different entities but all represent something which are compared in the area of adolescent health research and are the most relevant as they are used in this research study. An adverse status of any of the above parameters implies that the individual is at risk now and also at risk in the future. The health related definition of each differs greatly and what is classed as ‘at risk’ differs greatly too and each has a different strength of a relationship with current and future health risks. Body composition can be measured in many different ways and the methods will be discussed briefly in section 2.3.5.

### 2.3.1 Classification of ‘Overweight’ and ‘Obese’

Overweight and obesity can be classified in a number of different ways depending on the method used to assess body composition and also depending on age, gender and the different standards put forward. Childhood overweight and obesity levels can be defined based on the 2000 CDC age- and sex-specific growth charts for the United States (Centers for Disease Control and Prevention, 2002) or also on United Kingdom growth reference charts for children (Cole et al., 1995). Overweight is defined as having a BMI within the 85th to <95th percentile and obesity is defined as a BMI ≥95th percentile. Normal weight is defined as having an age- and sex-specific BMI >5th and <85th percentile. The World Health Organisation also put forward body mass index (BMI) ranges for the classification of overweight and obesity in adult populations (Table 2.4) and these are commonly used. These can be used for youth in extreme cases but a cutpoint related to the adult definitions were needed. The International Obesity Taskforce (Cole et al., 2000) put forward International Standard Cut-Off Points for
overweight and obesity based on representative data from six countries. These ranges of body mass indices allow prediction of whether a child may become overweight obese at age 18 based on their current BMI. This is important as just because a child is not classified as overweight or obese by adult standards, does not mean they are not at risk for developing the problem as an adult (Serdula et al., 1993). Irish studies that have utilised these cut-off points include the School Children and Sport in Ireland report (Fahey et al., 2005) which aids in comparisons between studies. In relation to interventional studies these cut-points can be used to target those ‘at-risk’ for overweight or obesity along with the overweight and obese, so to not isolate the already vulnerable child from their peers.

**Table 2.4 World Health Organisation BMI classifications for adults (World Health & Organisation, 1998, 2000, 2004)**

<table>
<thead>
<tr>
<th>Underweight</th>
<th>Normal</th>
<th>Overweight</th>
<th>Obese</th>
<th>Morbidly Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 18.5</td>
<td>18.5-25</td>
<td>25-30</td>
<td>≥30</td>
<td>≥35</td>
</tr>
</tbody>
</table>

Classification of overweight and obese using percentage body fat uses a difference classification system. Thicknesses of skinfolds using two or more anthropometric sites are used to calculate percentage body fat with ranges determining ‘normal’ or not. These would not be appropriate to use with adolescents.

**Table 2.5 Classification of percentage body fat ranges for adult men and women as per the American Council of Exercise**

<table>
<thead>
<tr>
<th></th>
<th>Women (% body fat)</th>
<th>Men (% body fat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential Fat</td>
<td>10-12%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Athletes</td>
<td>14-20%</td>
<td>6-13%</td>
</tr>
<tr>
<td>Fitness</td>
<td>21-24%</td>
<td>14-17%</td>
</tr>
<tr>
<td>Acceptable</td>
<td>25-31%</td>
<td>18-25%</td>
</tr>
<tr>
<td>Obese</td>
<td>&gt; 32%</td>
<td>&gt; 25%</td>
</tr>
</tbody>
</table>
2.3.2 Tracking of Overweight and Obesity to Adulthood

Power at al. (1997b) asked two important questions and while these questions are beyond the scope of this literature review, they can be discussed in relation to tracking:

(i) To what extent do overweight or obese children become obese adults?
(ii) Were obese adults overweight or obese children?

Studies have shown that childhood and adolescent overweight and obesity is significantly related to overweight and obesity in adulthood (Freedman, D. S. et al., 2005; Serdula, et al., 1993; Thompson et al., 2007; Whitaker et al., 1997) (DiPietro et al., 1994; Gunnell et al., 1998; Matton et al., 2006). Rapid weight increases between 0 and 6 months and 3 and 6 years is also a risk factor for an adverse weight profile in young adulthood (Ekelund et al., 2006b). In the study by Serdula et al. (1993) one third of obese preschoolers were predicted to become obese adults and this figure rises to half of school-aged children. Guo et al. (2002) demonstrated that children and adolescents at the 95th percentile BMI percentile had a 62-96% chance of becoming overweight at age 35. This is compared to only 10% at the 75th percentile who were at risk.

Adolescence represents a critical period in the development of obesity (Dietz, 2004) and also in developing physical activity and nutritional habits that track into adulthood (Kelder et al., 1994). The effect of age on the differing risk effect was shown by Gasser et al. (1995) when they found that overweight children have a better chance of improving their body composition state than overweight adolescents. Dietz (2004) found that up to 80% of overweight adolescents becoming obese adults. Females are often classed as more at risk. One third of 8 year old and younger females at the 95th, half of 8-13 year old females at the 95th percentile and two thirds of females over 13 were at risk of becoming obese at age 35 (Guo et al., 2002). This again demonstrates the effect of age on the risk for overweight and obesity. Fat mass is fairly stable over a period of 14 years with low fat mass being associated with high physical activity levels in both males and females (Kemper et al., 1999).

In relations to the original question posed at the beginning of this section, it can be concluded that the risk of becoming overweight or obese as an adult increases with the
child’s age and the greater the degree of adiposity (Freedman et al., 2005; Guo et al., 1994; Guo et al., 2002; Power et al., 1997a).

2.3.3 Irish Data on Obesity Levels

Early discussions about the rise in obesity levels and decrease in physical activity levels were based on international data and anecdotal Irish evidence. Yet it was difficult to say that physical activity levels were declining compared to past generations or that obesity levels were increasing since data from past generations was lacking. Irish studies are now beginning to provide evidence to back up these claims with some key studies tabulated in Table 2.7. The North South Food Consumption Survey (Irish Universities Nutritional Alliance, 2001) reported that since 1990 the prevalence of obesity has increased by 67% for males and females. The Growing Up in Ireland Survey (Economic and Social Research Institute, 2008) reported on the lives of over 8,000 9 year old children and will follow up with them at age 13. This will give longitudinal BMI data which may help answer the question if Irish children are becoming heavier. In the first wave of this first of a kind study in Ireland, the study group reported that 75%, 19% and 7% of 9 year olds were classed as normal, overweight and obese respectively (Institute, 2008).

Irish research into levels of overweight and obesity of the Irish population has relied on the Body Mass Index (BMI) as the principal measure of body composition. This measurement is not without its disadvantages and researchers have warned against the classification of the nation’s population as overweight using this measure (refs). Irish children’s weight profiles have been shown to have increased between the years 1970 and 2002 (Perry et al., 2008). The recent National Teens Food Survey reported BMI data for over 400 males and females aged 13-17. In relation to females aged 15 to 17 years, 84.2%, 13.8% and 2.0% were normal, overweight and obese as per the International Obesity Taskforce BMI cut-points (IUNA, 2008). Data from the Health Behaviour of School Aged Children (HBSC) from 15 countries was analysed and it was found that Ireland had one of the highest prevalence of overweight and obesity (Lissau et al., 2004). Table 2.6 presents BMI data from these two studies.
Table 2.6 Height, weight and BMI for age group from HBSC data (Lissau et al., 2004) and the North South Survey of Children’s Oral Health

<table>
<thead>
<tr>
<th></th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13 years</td>
<td>15 years</td>
<td>13 years</td>
</tr>
<tr>
<td>HSBC</td>
<td>50.7</td>
<td>55.1</td>
<td>159.3</td>
</tr>
<tr>
<td>Children’s Oral Health Survey*</td>
<td>52</td>
<td>59</td>
<td>157</td>
</tr>
</tbody>
</table>

*data cited in Perry et al. (2008). NR= Not reported in the paper

The School Children and Sport in Ireland report (Fahey et al., 2005) and the results of the TAKE PART study (Woods et al., 2004) would actually suggest that boys are just as at risk of becoming obese by age 18 as girls. But this study used simple height and weight measures to compute BMI and, as will be discussed, BMI tends to not favour those who possess more lean body mass and misclassification is possible (Heyward & Wagner, 2004:3). Females are classed as more ‘at risk’ for the future due to their low sports participation and physical activity rates.

2.3.4 International Data on Obesity Levels

The nomenclature of obesity as a ‘global epidemic’ infers the nature of the problem is global and international data back up this claim. Two large scale epidemiology studies from the United States show that the prevalence of obesity is rising (Bray, 2009). Data from NHANES (CDC, 2008; Ogden et al., 2007) and Behavioural Risk Factor Surveillance System (Mokdad et al., 1999) both show that levels of obesity have risen steadily from 1991 to 2007 (Figure 2.2). However, a more recent in-depth analysis of NHAHES data showed that levels of overweight and obesity from 1999-2008 are still rising but not rising at the same rate as previous years preceding (Flegal et al., 2010).
The World Health Organisation states that obesity in adolescents has increased dramatically between the years 1970 and 1991 from 5% to 13% in boys from 5% to 9% in girls (World Health & Organisation, 2004). 16% of children aged 6 to 19 years of age in the United States are considered to be overweight (Centers for Disease Control and Prevention, 2005) with the prevalence of overweight at least doubling in children ages 6 to 17 years of age between 1980 and 2000 (Dietz, 2004). More recently Ogden et al. (2006) found the prevalence of overweight increasing in children and adolescents between 1999 and 2004 with those at risk of becoming overweight (based on their current body mass index) also increasing.
<table>
<thead>
<tr>
<th>Study</th>
<th>Authors</th>
<th>Population</th>
<th>Findings</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical activity patterns in a nationally</td>
<td>Livingstone <em>et al.</em> (2008)</td>
<td>N=1379 18-64 year olds</td>
<td>20% men, 16% women overweight</td>
<td>BMI</td>
</tr>
<tr>
<td>representative sample of adults in Ireland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Teens’ Food Survey</td>
<td>IUNA (2008)</td>
<td>N=441 13-17 year olds</td>
<td>1 in 5 teenagers either overweight or</td>
<td>BMI, waisthip</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>obese</td>
<td></td>
</tr>
<tr>
<td>Relationship between physical activity,</td>
<td>Hussey <em>et al.</em> (2007)</td>
<td>224 7-10 year olds in Dublin</td>
<td>20.5 overweight and 6.3% obese</td>
<td>BMI and IOTF Cut-off Points used</td>
</tr>
<tr>
<td>inactivity, cardiorespiratory fitness and</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>body composition</td>
<td>Morgan <em>et al.</em> (2008)</td>
<td>N=10,364 Adults</td>
<td>Males 43% and 16%, Women 28% and 13%</td>
<td>Self report height and weight</td>
</tr>
<tr>
<td>Slán 2007</td>
<td></td>
<td></td>
<td>overweight and obese</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Morgan <em>et al.</em> (2008)</td>
<td>Subset of 967 Adults 18-44</td>
<td>Males 45% and 24%, Women 33% and 26%</td>
<td>BMI and waist circumference</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>overweight and obese</td>
<td></td>
</tr>
<tr>
<td>North South Food Consumption Survey</td>
<td>IUNA (2001)</td>
<td>N=1379 18-64 year olds</td>
<td>Males 41% and 14%, Women 25% and 12%</td>
<td>Self report height and weight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>overweight and obese</td>
<td></td>
</tr>
<tr>
<td>Slán 2002</td>
<td>Kelleher <em>et al.</em> (2003)</td>
<td>N=5992</td>
<td>Males 46% and 20%, Women 33% and 16%</td>
<td>Self report height and weight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>overweight and obese</td>
<td></td>
</tr>
<tr>
<td>TAKE PART</td>
<td>Woods <em>et al.</em> (2004)</td>
<td>1508 15-17 year olds in Dublin</td>
<td>17% and 3% females overweight and</td>
<td>BMI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>obese. Males 16% and 4%</td>
<td></td>
</tr>
<tr>
<td>Prevalence and awareness of excess</td>
<td>Yarnell <em>et al.</em> (2001)</td>
<td>2484 13-14 year olds in N. Ireland</td>
<td>16% and 2% girls overweight and obese.</td>
<td>BMI and IOTF Cut-off Points</td>
</tr>
<tr>
<td>weight in 13 and 14 year olds in Northern</td>
<td></td>
<td></td>
<td>16% and 4% boys</td>
<td></td>
</tr>
<tr>
<td>Ireland</td>
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</tr>
<tr>
<td>School Children and Sport in Ireland</td>
<td>Fahey <em>et al.</em> (2005) for the ESRI and</td>
<td>7,300 Primary and Secondary Students</td>
<td>16.6% and 3.8% girls (13-18 yrs) overweight and obese. 15.4% and 4.5% boys,</td>
<td>Self Reported height and weight used to compute BMI</td>
</tr>
<tr>
<td></td>
<td>Irish Sports Council</td>
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</tbody>
</table>
Table 2.8 Mean (± standard deviation) percent of overweight adolescents in the United States between 1999 and 2004 and also those at risk of becoming overweight (Ogden et al., 2006)

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overweight At risk of overweight</td>
<td>Overweight At risk of overweight</td>
</tr>
<tr>
<td>6-11 years</td>
<td>14.3 (± 2.1) 13.1 (± 2.4)</td>
<td>17.6 (± 1.3) 20.4 (± 2.5)</td>
</tr>
<tr>
<td>12-19 years</td>
<td>14.8 (± 1.0) 15.2 (± 2.3)</td>
<td>16.4 (± 2.3) 15.3 (± 2.3)</td>
</tr>
</tbody>
</table>

2.3.5 Methods to Assess Body Composition

Body composition is defined as the ratio of fat weight to body weight- or “the relationship between the ‘motor’ (exercising muscle mass) and the ‘baggage’ (body fat)” (Rowland, 1996: 49). The only way to truly accurately measure body composition would be dissection of the body (Brooks et al., 1999:597). As this is not possible the accepted gold standard for estimating body fat was once hydrostatic weighing (Brooks et al., 1999:597) (Baranowski et al., 1992) which is considered an indirect method. However, the new technology of dual-energy X-ray absorptiometry (DEXA) now provides a more accurate measure especially among children (Brooks et al., 1999:599; Rowland, 1996:53) (Rowland, 1996). These measures may not always be practical or feasible so non-laboratory based estimations are also available.

Field based methods for estimating body composition include skinfold measurements, electrical impedance and anthropometry (BMI, waist to hip ratio, somatotype). These are considered to be doubly indirect methods as they are based on underwater weighing techniques and are subject to errors inherent in densitometry as well as errors in the procedures themselves.

Body mass is simply the participants weight as measured on a weighing scales. BMI “is the mass divided by the squared weight and is considered to relate directly to body fatness” (Rowland, 1996:54) and even though it is not a direct measure of body fat, it is a widely used proxy measure of same (CDC, 2008). BMI is a simple and useful tool for the prediction of adult overweight and obesity from childhood data (Guo & Chumlea, 1999). The limitations of BMI have been well discussed (Rowland, 1996:54; Baranowski et al.,
with the most basic weakness being that it ignores the fact that muscle mass rather than fat mass may contribute to the excess weight relative to height (Rowland, 1996:54). Even so, BMI is widely used as an indicator of body composition in large scale epidemiological studies (Brooks et al., 1999:600; Freedman et al., 2005) even in studies where the critical relationship between body composition and diseases is being investigated (Hu et al., 2004; Wessel et al., 2004) at a population level. It is also used in interventional studies to measure change in obesity levels (Gortmaker et al., 1999) BMI has been found to be moderately correlated with body fatness measurements using DEXA (Daniels et al., 1997; Freedman et al., 2005) and reviews of literature found it is predictive of adult BMI (Freedman et al., 2005; Serdula et al., 1993). In terms of practicality it is quickly and easily measured using basic equipment and is suitable for a large number of participants with easy interpretation of results. Irish large scale studies have also relied on self-reported height and weight to estimate BMI (IUNA, 2001; Kelleher et al., 2003; Morgan et al., 2008). BMI data from the BRFS study shown in Figure 2.2 was estimated from telephone self report (CDC, 2008) and is about 10% lower than when BMI is measured using height and weight (Bray, 2009).

Percentage body fat is the percent of the body that is made up of fat. Percentage body fat can be measured in a number of different ways including skinfolds, air displacement plethysmography, DEXA and under-water weighing. Skinfolds are used to estimate body fat and can be expressed as percentage body fat relative to body weight (Heyward & Wagner, 2004:5). The sum of two or more sites is the preferred method of non-lab based body composition assessment for children (Freedson et al., 2000). High reliability and validity co-efficients have been reported on (Freedson et al., 2000; Baranowski et al., 1992) especially using more skinfold sites (Katzmarzyk et al., 1999). Errors for this technique include (Rowland, 1996:54):

(a) Individual differences in distribution of fat,
(b) Inter- and intra-tester variability in skinfold measurement,
(c) Problems with the equations used to calculate percentage body fat.

A larger sum of 5 skinfolds was significantly associated with lower MVPA in 9-10 year olds but this significant relationship was not seen between BMI and MVPA indicating that skinfold measurements and BMI are two separate constructs (Ekelund et al., 2004).
Waist to hip ratio is also used to assess abnormal fat distribution around the abdominal area. There is a high correlation between certain chronic diseases and fat stored in the abdominal region (Yusuf et al., 2005). Abdominal (central) fat distribution has also been associated with unfavourable concentrations of triglycerides, HDL and LDL, total cholesterol and blood pressure in children up to age 17 (Daniels et al., 1999; Freedman et al. 1999). Often this ratio is used in conjunction with BMI for calculating risk from obesity and its co-morbidities (World Health Organisation, 2000). A ratio above 0.8 for women and above 0.95 for men is considered a risk factor for metabolic diseases (Clark et al., 2008) and age-specific cut-off points for identifying high trunk fat mass have been put forward (Taylor et al., 2000).

One definite reason to monitor body composition would be to gain an insight into future population health and the economic costs (Gortmaker et al., 1993) associated with disease states. Bibbins-Domingo et al. (Bibbins- Domingo et al., 2007) projected that the current epidemic of adolescent overweight in the United States would considerably increase future rates of CHD.

### 2.4 Current Physical Activity Recommendations

Physical activity guidelines have changed in the last 20 years with the focus moving from blocks of high intensity activity towards accumulated activity at all intensities. The American College of Sports Medicine (ACSM) physical activity guidelines (Haskell et al., 2007) were published as an update to previous guidelines (Pate et al., 1995). The new guidelines state that healthy adults should accumulate 30 minutes or more of MPA on 5 or more days of the week or vigorous activity for at least 20 minutes on 3 days per week. This can be at a combination of intensities. This activity is in addition to light activities such as self care and casual walking and activities lasting less than 10 minutes in duration (walking around the home or office or to and from the car). Physical activity guidelines for children recommend 60 minutes of physical activity per day (Department of Health and Human Services, 2008) on most but preferably every day of the week. This too can be in accumulated bouts. British guidelines echo these recommendations for adults and children (O'Donovan et al., 2010). These recommendations update the previous recommendations ‘At Least Five a Week’ (2004) and are based on Australian guidelines.
and systematic reviews of the literature (Scottish Physical Activity Research Collaboration, 2009). The guidelines define children and young people as age 5-16 years and adults as 18-65 years and do not give any guidance towards the ages group of 16-18, the age that is of interest in the present study. Irish physical activity guidelines (Department of Health and Children, 2009) have followed the models from the United States and Australia. International guidelines and noted researchers were consulted when making these guidelines, seen in Table 2.9. Examples of each activity and guidelines to building these activities into daily life are given. The notion of counting shorter 10 minute bouts of activity towards daily physical activity is only mentioned as an extra note. For older people the addition of activities which increase muscular strength and endurance on 2 – 3 days per week are also mentioned.

A general physical activity recommendation with the goal of 10,000 steps (Tudor-Locke & Bassett, 2004) based on media campaigns and pedometer research has been put forward for adults. The classification is tabulated in Table 2.10. Evidence suggests that this 10,000 step recommendation is too low for children. Vincent & Pangrazi (2002) and Tudor-Locke et al., (2004) reported that 11,000 and 12,000 steps respectively for 6-12 year old girls 13,000 and 15,000 steps per day respectively should be attained. While there is increasing evidence of the step accumulation of children little attention has been given to the dose-response-what effect higher or lower step accumulations can have on health (Tudor-Locke et al., 2008).

Table 2.9 Irish Physical Activity guidelines Let’s Get Ireland More Active (2009)

<table>
<thead>
<tr>
<th><strong>Guidelines for children and young people (aged 2–18)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>All children and young people should be active, at a moderate to vigorous level, for at least 60 minutes every day.</td>
</tr>
<tr>
<td>Include muscle-strengthening, flexibility and bone-strengthening exercises 3 times a week.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Guidelines for adults (aged 18–64)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>At least 30 minutes a day of moderate activity on 5 days a week (or 150 minutes a week).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Guidelines for older people (aged 65 +)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>At least 30 minutes a day of moderate intensity activity on five days a week, or 150 minutes a week. Focus on aerobic activity, muscle-strengthening and balance.</td>
</tr>
</tbody>
</table>
Table 2.10 Classification of activity levels based on accumulated steps per day in adults (Tudor-Locke & Bassett, 2004)

<table>
<thead>
<tr>
<th>Activity Level</th>
<th>Steps/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>&lt;5,000</td>
</tr>
<tr>
<td>Low Active</td>
<td>5,000-7499</td>
</tr>
<tr>
<td>Somewhat Active</td>
<td>7500-9999</td>
</tr>
<tr>
<td>Active</td>
<td>≥10,000</td>
</tr>
<tr>
<td>Highly Active</td>
<td>≥12,500</td>
</tr>
</tbody>
</table>

2.4.1 Sedentary Levels

Sedentary behaviour is classed as any activity less than 1.5 times above the resting metabolic rate (1.5 METs). It includes activities like lying, sitting, watching television (TV), sitting listening to music, reclining and meditating (Ainsworth et al., 2000). The measurement of sedentary is initially hampered by its definition. Being sedentary is not just an absence of physical activity; just because a person does not meet physical activity recommendations does not mean they are sedentary (Pate et al., 2008). Standing also measures <1.5 METs so would be technically considered a sedentary behaviour. However, standing increases energy expenditure above resting rates and the contractions of the largest muscle groups (quadriceps and hamstrings) promotes lipoprotein metabolism (Hamilton et al., 2007). Standing has been, more recently, considered a break in sedentary behaviour (Healy et al., 2008a) and this standing time has its own protective effect (Healy et al., 2008a; Levine et al., 2005). This could be because people rarely stand perfectly still once standing, they fidget (Levine et al., 2005) and also upper body movements can accompany this standing time—self-care or housework activities for example.

Sedentary activity is described in detail in Chapter 8 and recent reviews have detailed links with health outcomes (Hamilton et al., 2007; Hamilton et al., 2009; Marshall et al., 2004). TV viewing time (Dunstan et al., 2007; Dunstan et al., 2004; Healy et al., 2008c), accelerometry measured sedentary and light activity (Healy et al., 2007; Healy et al., 2008b), time spent upright (Levine et al., 2005) and breaks in sedentary activity (Healy et al., 2008a) are all interlinked with health and metabolic profile risk factors in adults. Time spent sedentary, using TV viewing time as a proxy measure, was associated obesity in children (Dietz & Gortmaker, 1985; Gortmaker et al., 1996; Robinson, 1999). There is varying evidence on the mechanisms of how a sedentary lifestyle can negatively affect
health. Sedentary behaviours such as television watching, computer gaming, internet access, homework and reading are all seen as activities which could replace moderate and light physical activity (Hu et al., 2003). These activities, especially TV viewing and video gaming, are also associated with negative dietary behaviours (Utter et al., 2003). This lends credence to the link that TV and gaming levels have with overweight and obesity levels. Increases in physical activity have been shown to increase plasma HDL and decrease plasma LDL (Brownell et al., 1982). Inactivity has been shown to significantly decrease lipoprotein lipase (LPL) activity in rats (Bey & Hamilton, 2003) and results in decrease in muscle triglyceride uptake.

The interlink between sedentary patterns, physical activity levels and health outcomes are less well researched but studies have indicated that sedentary behaviours are associated to health outcomes independent of physical activity levels. Essentially the individual may meet physical activity recommendations yet still be at a health risk due to their sedentary patterns. This means that sedentary behaviour should be discouraged and included in physical activity recommendations (Hamilton et al., 2009; Healy et al., 2008a; Matthews et al., 2008). More research needs to be undertaken to look at sedentary activities and intensities at the lower end of the physical activity scale (Pate et al., 2008).

ActivPAL outputs in appendix 11.8 graphically illustrate the differences in physical activity and sedentary patterns that may mean they are at a different risk of disease. Appendix 11.9 (graph 3) shows what some researchers are now calling an active couch potato (Hamilton et al., 2009). This means that participants meet physical activity guidelines but are sedentary for the remainder of the day. Recent researchers have called for the development of prediction equations and thresholds to classify light and sedentary activities (Freedson et al., 2005; Matthews, 2005) and the use of monitors which directly measure body position (Clark et al., 2009; Matthews et al., 2008).

2.5 Physical Fitness

An edition of Research Quarterly for Sport and Exercise back in 1992 posed the question ‘Are American Children and Youth Fit?’ (Corbin & Pangrazi, 1992). The consensus from the collection of articles seemed to be that it is short-sighted to focus only on physical
fitness levels and assessment and that encouraging children to be regularly physically active is of equal or even greater importance (Corbin & Pangrazi, 1992; Freedson & Rowland, 1992). A change in physical activity levels would be more beneficial as activity levels have a greater connection to health and will also endure for long-term as it’s a lifestyle choice (Harris & Cale, 2006). Even so, physical fitness and its related parameters do have connections to CV health (Ortega et al., 2008) and should be assessed and monitored.

Physical fitness can be broken down into health related fitness parameters and those that are performance and skill related (Freedson et al., 2000) with those related to health being of greatest importance to monitor and change within the general population. Health related fitness parameters include CV fitness, muscular strength, muscular endurance and flexibility. CV fitness has the strongest relationship to health and it is also a parameter that other studies measure which allows for comparisons between studies. Cardiovascular fitness is defined as the ability to move large muscle groups for prolonged periods of time and depends on the functional state of the respiratory, cardiovascular and skeletal muscle systems (ACSM, 2005; 63). From this point on physical fitness shall just refer to the parameter of cardiovascular fitness.

2.5.1 Adult Cardiovascular Fitness Levels and Health

Prospective studies have shown that CV fitness is a predictor of all cause mortality even when adjusted for other unhealthy lifestyle habits and family history (Blair et al., 1989; Ekelund et al., 1988). Higher CV fitness would seem to attenuate the health risk of obesity (Ortega et al., 2007) such that an adverse body composition may not be as detrimental to those who are physically fit (Janssen et al., 2004; Lee et al., 1999). CV fitness combined with being a non-smoker and having a normal waist girth lowers the risk of CHD events (59%) and CVD (77%) and all cause mortality (69%) in men (Lee et al., 2009). Perhaps the more holistic approach would be to emphasise physical activity that can also develop the main component of fitness and increasing CV fitness during the prevention and treatment of obesity should be encouraged.
2.5.2 Adolescent Cardiovascular Fitness and Health

Adolescent cardiovascular fitness is related to CHD risk factors (Katzmarzyk et al., 1999), adiposity (Barbeau et al., 2007), emerging CVD risk factors and skeletal health (Ortega et al., 2008). Boreham et al., (2001) found that the relationship between CHD and body composition was stronger than that with cardiovascular fitness in a young adolescent population. Unlike studies mentioned earlier, the CHD and fatness relationship was not mediated by fitness. Evidence is also mounting that current CV fitness can influence future health. Findings from large scale studies such as the Muscatine Study (Janz et al., 2002), the Amsterdam Growth and Health Longitudinal Study (Twisk et al., 2002) and the Northern Ireland Young Hearts Project (Boreham et al., 2002) have related high physical fitness during adolescence to a healthier CVD risk factor profile at various stages of adulthood. Increases in VO$_2$max lowered insulin sensitivity in children with already elevated circulating insulin levels (McMurray et al., 2002). Low levels of CV fitness have been identified as possible modifiable factors associated with metabolic syndrome risk factors in children and youth (Eisenmann et al., 2005; Ekelund et al., 2009a). Studies have shown a tracking of physical fitness levels from early to late adolescence (McMurray et al., 2003) and adolescence to adulthood (Janz et al., 2000).

2.5.3 Methods of Measuring Cardiovascular Fitness

Questions have been raised over the validity of measuring CV fitness in children due to issues with administration, motivation and other factors which can affect fitness scores (Harris & Cale, 2006) and due to the merits of the measurement itself (Cale et al., 2007; Rowland, 1995). But as described earlier in this section, CV fitness is an important health parameter in adults and children so its measurement is also important. Maximal oxygen uptake (VO$_2$max) is the universally accepted and widely used lab measure of CV fitness (Malina, 1996) with the participant exercising to exhaustion on a cycle ergometer or treadmill. Although considered a gold standard, this procedure is unsuitable for field based research and unsuitable for certain populations as participants must exercise to exhaustion (American College of Sports Medicine, 2005). There is also large cost, time, inconvenience and expertise required (Boreham et al., 1990; Harris & Cale, 2006). Lab-based testing is not practical for ‘assessing fitness on a large scale and in terms of physical
activity promotion practice’ (Harris & Cale, 2006). Field-based fitness testing has advanced and is the norm. Examples of tests include the Cooper 12 minute run, 20 meter shuttle run test (20-MST), 1 mile run and half mile run. There are also walking tests which provide a reasonable measure of VO$_2$ max (Brooks et al., 2000:665).

2.5.3.1 The 20 Meter Shuttle Run Test

Also called the bleep test, the 20-MST (Léger & Lambert, 1982) was developed as a prediction tool for maximal oxygen uptake. Later Ramsbottom et al. (1988) developed a progressive shuttle run test which involves the participants running at variable speeds continuously between two markers 20 meters apart. Shuttle run tests have been used in large scale studies measuring CV fitness (Boreham et al., 2002; Powell et al., 2009). It is one of the most commonly used tests and it is employed in test batteries such as the FITNESSGRAM in the United States. It is a satisfactory test to measure CV fitness because of its ‘objectivity, standardisation, reliability, validity and availability of reference data’ (Ruiz et al., 2006). It has been validated against treadmill VO$_2$ max in 12-15 year olds (Liu et al., 1992).

2.5.3.2 Bruce and Modified Bruce Protocols

A variety of treadmill tests exist to measure CV fitness and the most common include the Brue protocol and its modification (Brooks et al., 2000: 657). The original Bruce protocol is aggressive as both the speed and the grade are increased so may only be suitable for fit and non-risk populations (ACSM 1995: 93). The Modified Bruce Protocol is the less aggressive version. Participants use the first 2 minutes as a warm up and the increases in both speed and gradient are less aggressive and more gradual. Some criticisms of the modified protocol include the fact that the first few stages are at a very low level of stress, become boring for the participant and are time consuming for the investigator. However, a lengthy warm up is essential for all aerobic tests so the early stages can also serve this purpose.

Nomograms and equations allow prediction of VO$_2$ from these treadmill tests using metabolic data associated with treadmill speed and gradient (Brooks et al., 2000: 280) (Heyward, 1998: 56). These are useful if direct measures of oxygen uptake are not
available. Indirect calorimetry is the preferred method and this is described in section 2.7.1.1 and can be used in conjunction with treadmill or ergometer protocols.

2.6 Blood Pressure and Health

A review of 61 studies encompassing over 1 million participants confirmed that high blood pressure is related to stroke, vascular problems and overall mortality from middle to old age. This is for people with no history of hypertension and with normal blood pressure at baseline. (Lewington et al., 2002). Physical training can have a small but clinically significant reduction in blood pressure in normotensive participants (3/2 mmHG) and 7/6 mmHG reduction in those with elevated blood pressure (Fagard, 2001). This is why it was important to measure blood pressure even in seemingly healthy participants. For risk prediction, systolic blood pressure gives slightly better information than diastolic blood pressure (Lewington et al., 2002). Physical training reduces blood pressure (Fagard, 2001) so unsurprisingly blood pressure interest groups recommend physical activity for reducing and preventing hypertension (Chobanian et al., 2003).

2.7 Physical Activity Assessment

Physical activity has been defined as ‘any bodily movement which expends energy’ (Casperson et al., 1985) and as a result is much more than sport, structured exercise or work. The energy expenditure resulting from physical activity (Trost, 2007) can be divided into activity and non-exercise activity thermogenesis or NEAT (Levine, 2005). Accurate and valid measures of physical activity are required to estimate energy expenditure and physical activity and relate these to disease states and to assess the effectiveness of physical activity interventions (Freedson et al., 2005; Sirard & Pate, 2001; Westerterp, 1999). Patterns, levels and intensities of physical activity and the link between these bodily movements and health are of interest to doctors, researchers, teachers and caregivers as they strive to understand what level of physical activity and physical inactivity impacts on population health. The decision on which assessment method to use can depend on what outcomes measures are of interest.
Physical activity can be expressed in a number of different ways (Trost, 2007):

(i) Energy Expenditure per day/week (kilocalories, kilojoules),
(ii) Metabolic Equivalents (METs),
(iii) Total time spent in various intensities of physical activity,
(iv) Blocks of time in various intensities of physical activity,
(v) Duration and frequency of these blocks or bouts of physical activity.

Since physical activity and bodily movements are multifaceted, so are the physical activity assessment methods available (Janz, 2006). Many physical activity assessment methods exist each with their own inherent advantages and disadvantages and each method can serve a different purpose and produce different outcome variables. Techniques can be grouped depending on the metabolic method used (Levine, 2005):

(i) Indirect calorimetry- where VO$_2$ and VCO$_2$ are measured and converted into energy expenditure,
(ii) Direct calorimetry- heat loss is measured,
(iii) Non-calorimetric- predicting energy expenditure from observational, physiological and mechanical outputs.

The techniques can also be grouped depending on the nature of the technique itself (Westerterp, 1999):

(i) Behavioural observation,
(ii) Questionnaires,
(iii) Physiological variables,
(iv) Calorimetry,
(v) Motion sensors.

Comprehensive reviews of physical activity measurement have outlined the advantages and disadvantaged of each individual method (Kohl et al., 2000; Melanson & Freedson, 1996; Rowlands & Eston, 2007; Sirard & Pate, 2001; Trost, 2007) with some focusing on objective measurement exclusively (Corder et al., 2008; de Vries et al., 2006; Rowlands & Eston, 2007). The following sections will describe laboratory and field measures of physical activity.
2.7.1 Laboratory Measures of Physical Activity

2.7.1.1 Indirect Calorimetry

One technique under the heading of indirect calorimetry is expiratory collection open circuit system. It measures energy expenditure from oxygen uptake and carbon dioxide production. A mouthpiece or a mask is connected to a one-way valve where expired air enters the sampling instrument. The flow rate of expired air through the valve is measured and expired air is diverted to a mixing bag that is analysed at the end of each measurement period. The advantage of this approach is that the calorimeter can be designed as a portable device so that energy expenditure can be measured in free-living individuals and activities. This is only suitable for short term monitoring (Levine, 2005; Sirard & Pate, 2001). Indirect calorimetry is one of the most commonly used criterion measures when validating an accelerometer (Trost, 2007).

2.7.1.2 Direct Observation

Direct observation would be classed as non-calorimetric and is not associated with a laboratory environment as it can be used outside of a laboratory setting. However, it cannot be used to measure habitual physical activity in daily life and is mostly used in discreet settings such as lunch break activity or PE classes. It involves trained observers witnessing a physical activity session and coding what they observe using a handheld computer (Kohl et al., 2000). Direct observation gives important information on patterns and location of physical activity and it is useful for assessing play patterns, intensity of PE classes and equipment used (Trost, 2007). Details of validation studies of the various direct observation techniques are available (Kohl et al., 2000; Sirard & Pate, 2001).

2.7.2 Free Living Measures of Physical Activity

There is an extensive range of methods and devices to measure free living physical activity available to researchers and each have their own advantages and disadvantages. An online physical activity decision matrix has been designed by the Medical Research Council in the UK to help practitioners to choose a method which may best suit their needs and resources (http://toolkit.s24.net/physical-activity-assessment/index.html). Each method is described in detail. Four measures of physical activity that can be applied
in the field that were feasible for this present research will be discussed below. These are heart rate monitoring, self report, pedometry and accelerometry. Doubly labelled water is also described briefly.

2.7.2.1 Doubly Labelled Water

The doubly labelled water method relies on the participant drinking stable, non-radioactive isotopes (H\textsuperscript{2}O\textsuperscript{18}) which tag oxygen and hydrogen. Measuring the amount of H\textsuperscript{2}O\textsuperscript{18} excreted can give an estimate of carbon dioxide production and thus energy expenditure. The advantages are that estimates can occur for a total of 14 days and is easily administered and accepted. However, this method is expensive, can only estimate total energy expenditure and it does not give information on duration, intensity and frequency of the physical activity (Kohl \textit{et al.}, 2000; Sirard & Pate, 2001).

2.7.2.2 Heart Rate Monitoring

Heart rate telemetry is commonly used as an objective measure of physical activity in children and adults. It is an indirect measure as it is based on the assumed linear relationship of the heart rate response to physical exertion (Sirard & Pate, 2001; Trost, 2007). The advantages are it is objective, relatively inexpensive and can record over time. However, heart rate monitoring by definition is a measure of a physiological variable and can be affected by factors such as emotion, environmental conditions, fitness level and lifestyle habits such as caffeine ingestion and smoking (Hiilloskorpi \textit{et al.}, 1999) especially at rest. Also a fitter child will respond to the same intensity of exercise with a lower heart rate compared with a less fit child. This problem can be overcome by using individualised heart rate- VO\textsubscript{2} calibration curves to reduce the variability associated with heart rate differences between sexes, ages, weight status and fitness levels (Levine, 2005; Strath \textit{et al.}, 2005). This can be time consuming, requires specialised knowledge and may not be suitable for large scale studies. Children studies in Britain (Eston \textit{et al.}, 1998) and Ireland (Belton & MacDonncha, 2007; Shiely & MacDonncha, 2009) have used heart rate monitoring to assess physical activity but have accepted its limitations which include low compliance and technical problems.
2.7.2.3 Self Report Measures

Self report is the most commonly employed measure of physical activity from past literature and in large epidemiological studies. Self report includes self report diaries and recall questionnaires (Kohl et al., 2000). Telephone administered recall and parental and teacher report can be used with young children (Trost, 2007). The advantages of self report is that it is low cost, convenient, quick and easy to use for both the administrator and participant, unobtrusive and information on location and type of activity can be obtained (Kohl et al., 2000; Trost, 2007). Self-reporting is limited by reporting bias which can be due to a number of factors (Sallis & Saelens, 2000a). These include overestimation of moderate and vigorous physical activity (Adamo et al., 2009; Sallis et al., 1996), the participant giving the socially desirable answer; ‘telling then what they want to hear’ and problems young people, especially children have in recalling physical activity bouts (Janz, 2006). Self report also struggles to pick up unplanned habitual physical activity which is important for overall energy balance.

Reviews of the relevant studies validating self report to direct measures of physical activity and energy expenditure have found a low to moderate relationships (Adamo et al., 2009; Corder et al., 2008; Gortmaker et al., 1999; Prince et al., 2008; Sallis & Saelens, 2000b; Shephard, 2003). No clear pattern or conclusion could be drawn about the level of difference between self report and the direct measures. However in general girls overestimated more than boys and the level of difference depended on the direct measure chosen for comparison and the intensity of the activity. High intensities are misclassified the most. Slootmaker et al. (2009) found large differences in self reported MVPA between a self report questionnaire and accelerometer among adolescents. Gender, education and body mass all affected the magnitude of the difference (Slootmaker et al., 2009).

Children’s own perception and their parents perception of their activity levels was measured by Corder et al. (2010). Over half of the 10 year old cohort correctly classified their physical activity levels using a simple ‘are you more or less active than your peers’ question compared to accelerometry. However, more inactive children overestimated their actual physical activity levels and parents of inactive children wrongly classify their children as sufficiently active. Parents of children with a more favourable body composition assumed that their child must be sufficiently active (Corder et al., 2010).
Basterfield et al. (2008) reported that when using a public health physical activity survey in the UK, 83% of 6-7 year old boys and 56% of girls met the 60 minute physical activity recommendation. Using accelerometry, this figure drops dramatically to 3% and 2% of boys and girls respectively (Basterfield et al., 2008). Similar discrepancies have been reported from the National Health and Nutritional Examination Survey (NHANES) from the United States when objective data was compared to past subjective results (Troiano et al., 2008).

There are many self report questionnaires and checklists available to researchers and this means that direct comparisons are hampered. It is necessary to convert the results to measures that can be compared for example minutes of MVPA, estimated METs etc. The same can be said for objective monitoring too and this problem with accelerometers will be discussed in section 2.8.4.14. The Self Administered Physical Activity Checklist (SAPAC) is one such questionnaire developed by Marshall et al., (2002) and is a recall checklist for the previous 7 days. It has been modified for Irish usage and was used successfully in the TAKE PART study (Woods et al., 2004). A 24-hour version (Sallis et al., 1996) also exists but investigators feel that the longer recall time would reveal habitual activity patterns and reduce the likelihood of recording infrequent behaviour (Woods et al., 2004). Conversely, longer time frames mean recall can be made more difficult especially with younger cohorts. Studies have shown that participants tend to underestimate moderate physical activity bouts and this is an intensity which is quite important in adolescent epidemiological studies.

A general assessment of habitual physical activity levels can be done using a self report measure developed for use with adolescents (Prochaska et al., 2001). Participants simply report the number of days during the past 7 days, and during a typical week that they had accumulated 60 minutes of MVPA and the mean of the two values resulted in the average number of days that the participant was active for 60 minutes or more in the previous week. Physical activity was defined as activity that “increases your heart rate and makes you get out of breath some of the time” and examples such as basketball and dancing were given. The average of the two was used as a composite score for habitual physical activity. The tool has acceptable reliability and validity in younger children (Booth et al., 2001). This screening tool was used as a measure of habitual physical activity in the Health Behaviours of School Aged Children Survey (Borraccino et al.,
2009; Kelleher et al., 2003) and the TAKE PART Study (Woods et al., 2004) and a cross-sectional study in the United States (Butcher et al., 2008).

Even though accelerometry would be seen as the ‘gold standard’ for large scale free living physical activity assessment, questionnaires and surveys are regularly used (Barbeau et al., 2007; Evans et al., 2009; Gortmaker et al., 1999; Powell et al., 2009; Schneider et al., 2008; Schofield et al., 2005; Young et al., 2006). Self report is also satisfactory for large scale studies where population levels rather than individual levels were important or if cost is an issue. In general the conclusion would be that self report methods would provide an acceptable detail of physical activity in older children especially if type and location of the physical activity is of interest (Corder et al., 2008; Trost, 2007).

2.7.2.4 Pedometers

A pedometer is a small, unobtrusive, cheap and easily available device which measures total volume of ambulatory physical activity (Sirard & Pate, 2001; Tudor-Locke & Lutes, 2009). It measures steps using a mechanical sensor like a spring suspended lever arm which moves up and down as a step is taken. These steps are registered and recorded on a digital screen for the wearer to see. A validity study found hip mounted pedometers to correlate with oxygen uptake between 0.62 and 0.93 (Eston et al., 1998). This was during children’s play and the relationship between pedometry and step intensity is less well researched as oxygen uptake can vary depending on whether walking or running is being measured.

Where large scale studies are concerned pedometers are a more cost effective alternative to accelerometers (Trost, 2007) and a more objective alternative to self report. The main limitation is that the intensity of the movement (step) is unknown and the frequency, intensity or time of the activity is unknown (Sirard & Pate, 2001; Trost, 2007). Studies use pedometers for motivational purposes (Schofield et al., 2005) as health professionals push participants towards the adult goal of 10,000 steps per day (Tudor-Locke & Bassett, 2004). Pedometers have also been used by Lubans and Morgan (2008) and Lubans et al. (2009) to measure physical activity during and after interventions.
2.8 Measuring Physical Activity Using Accelerometry

Many significant advances in the area of objective physical activity monitoring have occurred in the last decade (Trost et al., 2005; Westerterp, 1999). Motion sensors such as accelerometers hold the most promise to overcome the previously described limitations of doubly labelled water (Ainslie et al., 2003) and self-report (Troiano, 2006). Accelerometry falls under the heading of objective motion sensors and can be defined as the measurement of bodily movement in terms of accelerations, which can then be used to estimate physical activity intensity (Chen & Bassett, 2005; Troiano, 2005). They provide real time monitoring of activity quality and quantity (Freedson et al., 2005) in terms of activity counts and step rates while also estimating intensity and energy expenditure from these.

Accelerometers measure bodily accelerations by using one or more piezoelectrical acceleration sensors containing a piezoelectrical element and a seismic mass within a case. When the sensor is subject to acceleration, the seismic mass above or to the side of the element moves and causes the element to bend or deform. This deformation produces a variable output voltage signal proportional to the acceleration (Chen & Bassett, 2005). Once the data has been sampled at a particular frequency, it is filtered at a particular bandwidth frequency to ‘clean’ the data of noise that is not physiologically possible. This data is then converted from an accelerational value and processed into a meaningless number known as an activity count. The proprietary algorithm then sums the activity counts into the preset or user defined epoch (recording period).

Accelerometers can be uniaxial and record in a single axis, usually the vertical (Plasqui & Westerterp, 2007), while more sophisticated triaxial accelerometers work in the x, y and z planes of movement. These more sophisticated devices record the actual direction and magnitude of accelerations in the three planes allowing the intensity of the movement to be estimated from the raw data (Hendelman et al., 2000). The 3 separate and unique planes are often combined into a composite outcome value (Chen & Bassett, 2005). This will be discussed further in section 2.8.4.1.

The objectivity, ease of use, non-invasive nature and validity under most (but not all) circumstances of accelerometers means that many researchers are availing of this
developing technology. One caveat to their use would be that these monitors underestimate energy expenditure in weight bearing activities, upper body movements and ambulation up stairs or an incline (Trost, 2001). Non-ambulatory lower body movements like cycling are also not assessed well (Schmitz et al., 2005). However, the contribution of these activities to normal physical activity is considered negligible (Westerterp, 1999). In 2005, Chen and Bassett reported that most accelerometers cannot detect the static component of acceleration so cannot distinguish standing versus sitting. Only a year before, Mathie et al. (2004) wrote that accelerometers can respond to acceleration due to gravity and due to body movement making them useful for measuring body position (posture) and bodily movement at various intensities. It is not clear where this discrepancy lies.

Popular commercial accelerometers will be discussed in section 2.8.1 and validation and calibration with various target groups will be discussed in section 2.8.2. Common issues with these validation studies will be discussed in section 2.8.3 as researchers strive to identify and overcome common problems. In general, the consensus would be that accelerometry is an invaluable addition to any study that aims to quantify discreet short episodes of movement or to monitor activity and inactivity patterns (Janz et al., 1995; Janz, 2006).

2.8.1 Commercially Available Accelerometers

Portable accelerometers have been investigated as far back as 1983 (Montoye et al., 1983). Early landmark validation studies took place from 1995 onwards but it is only since 2001 that there has been a dramatic increase in publications related to physical activity and accelerometry in children (Rowlands, 2007). Early research was undertaken using the CALTRAC (Muscle Dynamics Fitness, Torrance, CA) accelerometer (Miller et al., 1994; Sallis et al., 1990). The Actigraph accelerometer, also known as Computer Science Applications Inc. (CSA) and Manufacturing Technologies Inc. (MTI) is one of the most commonly used physical activity monitoring devices (Dencker & Andersen, 2008; Rowlands, 2007). This has been both due to and resulted in many calibration and validation studies in various populations which will be detailed in section 2.8.2. Other popular accelerometers include the RT3 Triaxial, formerly the Tritac (Stay Healthy Inc,
Monrovia, CA) and the Actical and Actiwatch (both MiniMitter Inc, Bend, OR). The details of these devices have been previously well described (Chen & Bassett, 2005) and they are beyond the scope of this literature review.

Recognising the limitations of waist worn accelerometers, newer physical activity monitors now incorporate multiple sensors and physiological measurements to enhance their energy expenditure estimates. The Intelligent Device for Energy Expenditure (IDEEA, MiniSun LLC, Fresso, CA) consists of 5 small sensors that are attached to the chest, thighs and feet. The different combinations of signals represent 32 diverse yet specific different activities including such as lying face down, sitting with both feet elevated, leaning with two elbows on a counter and standing with right foot on a step (Zhang et al., 2003). The SenseWear Pro Armband (BodyMedia Inc, Pittsburg, PA) uses galvanic skin response and temperature receptors to enhance its measure of energy expenditure (Andre et al., 2006). The Actiheart (Cambridge Neurotechnology, UK) incorporates simultaneously heart rate monitoring along with an accelerometer motion sensor (Brage et al., 2005). The advantages and limitations to each device must be carefully considered before making a decision on the right device to use (Welk, 2005).

2.8.2 Calibration and Validation of Accelerometers

Before the output of an accelerometer can be used with confidence it needs to be independently assessed to make sure it measure what it should be measuring. This is called value calibration or validity (Welk, 2005). A challenge in accelerometry-based approaches is that the raw outputs, referred to as counts, must be converted into a meaningful physiological variable (Matthews, 2005) and interpretable unit. This is known as calibration and is when the counts are related to oxygen uptake, metabolic equivalent (MET) or caloric expenditure to give a more meaningful and interpretable measure of physical activity intensity (Freedson et al., 2005; Schmitz et al., 2005).

A further description on accelerometry calibration can be found in Chapter 4. This section is not intended to be a comprehensive review of all the validation and calibration studies as this has already been covered by eminent research groups (Cliff et al., 2009; Freedson et al., 2005; Kohl et al., 2000; Matthews, 2005; Rowlands, 2007; Trost, et al.,
2005; Westerterp, 1999). Rather, some of the key studies have been selected to highlight developments in validation and calibration studies and some common issues that researchers encounter as they endeavour to further our understanding of physical activity.

The Actigraph/CSA/MTI has been calibrated against doubly labelled water (Adams et al., 2005), indirect calorimetry (Freedson et al., 1998; Hendelman et al., 2000; Schmitz et al., 2005) and whole body calorimetry (Puyau et al., 2002). Correlations have ranged from 0.45 to 0.98 depending on the population, the activities and the criterion method used (Janz, 1994; Nichols et al., 2000; Puyau et al., 2002). The Actigraph has also been shown to be a valid measure of EE during treadmill walking in children (Trost, et al., 1998) and for free living EE compared to doubly labelled water (Ekelund et al., 2001; Plasqui & Westerterp, 2007). The Caltrac and the Tritrac have both been compared to indirect calorimetry in adults (Fehling et al., 1999) and in children over a variety of activities (Eston et al., 1998) and reported correlations up to 0.91. Welk and Corbin (1995) reported relationships of 0.46 to 0.74 between heart rate monitoring and the Tritrac triaxial in 9-11 year olds. Carter et al. (2008) compared activity counts per day of the 3dNX accelerometer to doubly labelled water measured energy expenditure in adolescents and young adults. They reported correlations of 0.52 for adolescents and 0.59 for young adults.

2.8.3 Issues Surrounding Calibration and Validation Studies

The commercially available accelerometers mentioned in section 2.8.1 have been calibrated and validated in difference populations and using different protocols. Little attention has been given to the standardisation of data collection, data analysis and data interpretation resulting in problems when comparing data (Freedson et al., 2005; Mathie et al., 2004). Reviews have attempted to address these issues and offer counsel to researchers embarking on validation or calibration studies (Freedson et al., 2005; Welk, 2005). Factors in these studies which can be questionable are the choice of criterion or ‘gold standard’ measure that the monitor is compared to, the activities used and the statistical and interpretational treatment of the data.
2.8.3.1 Criterion Measure Used

The majority of validation studies have compared accelerometers to indirect criterion measures such as doubly labelled water (Bouten et al., 1996; Ekelund et al., 2001; Plasqui & Westerterp, 2007), whole body calorimetry (Puyau et al., 2002), or indirect calorimetry (Eston et al., 1998; Freedson et al., 2005; Levine et al., 2001; Trost et al., 1998). Doubly labelled water is considered the ‘gold standard’ (Ainslie et al., 2003). Section 2.8.2 described the various measures that accelerometers have been compared against.

2.8.3.2 Activities in the Protocol

To predict the relationship between accelerometer output and energy expenditure calibration studies are employed to relate activity counts to a physiological and interpretable unit under a wide range of conditions. The choice of conditions (activities and speeds) that are included in the validation and calibration studies can be a source of error in many ways. Landmark studies (Freedson et al., 2005; Freedson et al., 1998; Melanson & Freedson, 1995; Trost et al., 1998) have used a standard locomotor protocol where participants simply walk and jog on a treadmill at various speeds to elicit a wide range of ambulatory intensities (Matthews, 2005; Welk, 2005).

More recent studies have used a range of free living activities to validate the particular accelerometer (Matthews, 2005). The rationale for this is that the inclusion of a range of activities would reflect the different types of activities that people would do in daily life. Often the activity pattern and the subsequent counts are homogenous when walking or jogging at a constant speed on a treadmill, but in reality youth (especially children’s) physical activity can occur over a wide variety of intensities, speeds and axis and therefore the subsequent counts are more heterogeneous (Eston et al., 1998). In calibration studies with children activities such as colouring and hop scotch are used (Eston et al., 1998). In studies with adolescent females activities such as watching TV and shooting basketball have been used (Treuth et al., 2004a). In adult studies normal household chores like window washing and mowing grass have been utilised when validating an accelerometer (Hendelman et al., 2000). In a unique analysis of free living activities, Matthews (2005) demonstrated the effect that the activities can have on the resultant regression equation relationship between counts and energy expenditure. The strongest relationship came from sitting, walking and running only while excluding sitting.
and/or adding box moving (a static complex activity) affected the intercept of the regression equation and thus the accuracy of the prediction equation (Matthews, 2005). Welk et al. (2000a) found better correlations between measured VO$_2$ and treadmill activities ($r=0.86$) compared with lifestyle activities ($r=0.55$).

There is varying opinion on the difference between accelerometry outputs from treadmill based walking compared to overground walking (Levine et al., 2001). Differences can come from treadmill experience or habituation, treadmill mechanics and ground reaction forces production (White et al., 1998). Results confirm the same especially in light and vigorous intensities (Nichols et al., 2000). Another common problem is that accelerometers, especially 1-D devices, do not pick up the added energy cost of walking up an incline (Levine et al., 2001) (Melanson & Freedson, 1995). It could be argued that incline walking may only be a tiny portion of total free living activity. Also, the inclines used for device testing are often larger than the inclines normally encountered in free living activity. For example, Levine et al., (2001) used grades of 17.5 and 22.1 degrees in their validation study.

A less well-researched area is validation of these regression equations in a field setting where many would be used for general populations. The limitations of treadmill based calibration equations have been shown in field and free living activities (Guinhouya et al., 2006; Reilly, et al., 2008; Stone, et al., 2009; Trost, et al., 2006). Systematic underestimation at lower intensities and over estimation at higher intensities has been reported (Freedson et al., 2005). Equations based on treadmill or overground walking and running do not represent of normal free living activity (Hendelman et al., 2000; Melanson & Freedson, 1995) so it is not surprising that hip worn monitors underestimate energy expenditure when applied to daily living (Welk et al., 2000a). While it may be inappropriate to apply treadmill based equations to free living situations (Hendelman et al., 2000) it is regularly done especially if no equation other than a treadmill one is available.

### 2.8.3.3 Levelling off of Counts at Higher Speeds

Studies which look at step rates and accelerometer outputs at increasing speeds have concluded that while outputs increase linearly during walking/jogging, they level off or even drop during running (Brage et al., 2003; King et al., 2004). It could be said that
uniaxial accelerometers may not be suitable for use with athletes, those engaging in structured exercise or those who get their daily MVPA through running. For general populations who participate in walking for exercise this should not be an issue.

2.8.3.4 Individual versus Group Calibration

Using heart rate as a measure of physical activity work rate requires individual calibration due to the variances in the heart rate response to exercise. Individual calibration of accelerometers has been suggested (Brage et al., 2007; Levine et al., 2001) but not fully explored. The variability found in energy expenditure for the same activities (Pfeiffer et al., 2006) and accelerometer outputs at the same walking speeds (Ekelund et al., 2003) would suggest that individual calibration is necessary. Stone et al., (2009) found no difference between individual or group calibration of the specific sample compared with using a previously published threshold. All published equations can predict mean energy expenditure at group levels but are less accurate in individuals (Melanson & Freedson, 1995) making individual calibration necessary if small or exact measurement is required.

2.8.3.5 Treatment of the Data (Creating a Regression Equation)

Regression analysis is when an outcome variable is predicted from one or multiple predictor variables (Field, 2009; 198). In this context it would mean prediction energy expenditure using an accelerometer output such as counts. Fitting a linear regression model for complex movement activities may be a source of error. The relationship mentioned may not always be linear (Freedson et al., 2005) and it can affect the goodness of fit the equation and for using the equation in further free-living situation (Hendelman et al., 2000). Mixed modelling has been proposed to overcome this and will be discussed in section 5.2.5. What this regression equation includes is also important. Studies have included age, sex or body mass as a potential predictor. Age was taken into account when estimating EE by Puyau et al. (2002) but when estimating activity EE, the regression relationship was independent of age and sex.

Often validation studies will use the standard agreed oxygen uptake of adults of 3.5ml.kg.min$^{-1}$ at rest (Brooks et al., 2005). This is erroneous as youth resting metabolic rate (RMR) declines throughout youth until it reaches adult level at age 18. There is also variation in this RMR between adolescents; Pfeiffer et al. (2006) reported at 24.3%
variation in 74 adolescents aged 13 to 14. Other studies measure each child's RMR (Puyau et al., 2002; Treuth et al., 2004a) and base subsequent MET calculations on individual RMR. Studies reporting METs in children should measure RMR or use age-specific estimates of energy expenditure at rest (Freedson et al., 2005).

2.8.3.6 Summary

A lack of standardised protocols have hampered the progress of objective physical activity monitoring making it difficult to compare results between studies, research groups, populations and monitors (Matthews, 2005). The next section will present many of the issues that researchers face when planning a study using accelerometry.

2.8.4 Guidelines for Accelerometry Usage - Building a Protocol

There are many methods employed in accelerometry usage reported in the literature and in section 2.8.2. Differences in calibration, practical usage, data analysis and data reporting means that there is no standard best practice protocol for accelerometry and many gaps and inconstancies abound (Troiano, 2005; Ward et al., 2005). To that end, a meeting which results in a set of research articles ("Objective monitoring of physical activity: Closing the gaps in the science of accelerometry," 2005) focused on some of these issues. It included reviews focused on the practical issues surrounding accelerometry that need to be addressed before a free-living study should take place (Mâsse et al., 2005; Matthews, 2005; Trost et al., 2005; Ward et al., 2005; Welk, 2005). Since then other reviews have focused on usage (Reilly et al., 2008) and issues and usage in specific populations such as pre-schoolers (Cliff et al., 2009), children (Corder et al., 2008; Rowlands, 2007) and older people (de Bruin et al., 2008; Murphy, 2009). From the first step of selecting an accelerometer to the final step of reporting the data, guidelines and issues to consider when planning accelerometry based research in the field can be summarised under the next following 14 headings. These are based on best practice review papers and also using examples from other accelerometry papers.
2.8.4.1 Selection of a Commercially Available Accelerometer

The literature is divided over the optimal accelerometer to use in relation to validity (Rowlands, 2007). The goal of the research and the research question needing to be answered may influence the choice of monitor (Welk, 2005) but other practical factors may also be taken into account (Ward et al., 2005). These include initial and ongoing unit costs, unit size and memory capabilities and technical support available (Cliff et al., 2009; Rowlands & Eston, 2007; Trost et al., 2005). It will also depend on the population being sampled. For example, in a population of children younger than 5 years old the accelerometer would need to be durable, sturdy and tamper proof (Cliff et al., 2009). For older adults the accelerometer should be able to effectively record light activities (Murphy, 2009). The Actigraph (Actigraph LLC, Florida) is one of the most widely used accelerometers (Rowlands, 2007) and it is seen as an accepted standard in accelerometry and activity monitoring (Dencker & Andersen, 2008; Trost et al., 2006). Some differences exist between the different generations of models (7164, 71256 and GT1M) of the Actigraph (Corder et al., 2007; Rothney et al., 2008). The literature should be consulted as to which make and model of monitor are most reliable, valid and dependable.

During walking, the majority of the action occurs in the vertical plane which one dimensional (1-D) or uniaxial accelerometry picks up. A debate in the literature is whether a three dimensional (3-D) recording device may be of more benefit as it would pick up movement in all the planes. While the vertical plane is the most important to record (Eston et al., 1998) the added benefit of having an extra 2 dimensions is not unequivocal. Welk et al. (2000a) found that a uniaxial, biaxial and triaxial accelerometer all significantly underestimated the energy expenditure of household and complex activities. 3-D may be important when measuring children’s physical activity. Eston et al. (1998) and Trost et al. (1998) found that a 3-D accelerometer was a better predictor of children’s $\text{VO}_2$ than the vertical axis alone. 3-D may also be important for use with participants who engage in a lot of high speed running. The horizontal axis becomes increasingly more important to movement as participants move from a walk to a jog and a jog to a run. A levelling off of the counts or a ‘ceiling effect’ can occur at these higher speeds using a 1-D (Brage et al., 2003) but the extra 2 dimensions may overcome this.
2.8.4.2 Number of Accelerometers on Each Participant

It is well established that a single waist mounted monitor will not capture the full range of daily energy expenditure (Matthews, 2005; Strath et al., 2005). An additional accelerometer on the ankle or wrist may yield extra, important information but when the extra cost, invasiveness and participant burden is considered (Trost et al., 2005; Ward et al., 2005) it may not be necessary with the average participant (Westerterp, 1999). Melanson and Freedson (1995) demonstrated that energy expenditure equations based on data from an ankle, wrist as well as the traditional hip CSA accelerometer is more accurate ($r=0.95$ compared to $r=0.85$). The accepted list of activities that hip mounted accelerometers do not measure include swimming, walking up stairs or incline and upper body resistance exercises. These activities can be captured using a concurrent diary and accelerometer output can be then revised (Matthews, 2005). The contribution of daily light activities to overall energy expenditure (Levine et al., 1999; Westerterp, 2001), such as sweeping or washing the dishes, which may be missed by a lower body accelerometer. Unless investigators envisage a unique movement pattern (Trost et al., 2005) or a large amount of upper body activity (as with wheelchair bound people) or are looking for accurate measured of daily energy expenditure one monitor should be adequate.

2.8.4.3 Placement of the Accelerometer

The placement of the accelerometer is dependent on the manufacturer recommendations. Trost et al. (2005) wrote that it should be ideally attached as close to the body’s centre of mass as possible. Researchers support the positioning at the hip or lower back (Ward et al., 2005) and in direct contact with the skin (Westerterp, 1999). Other accelerometers which also measure posture and inclination are placed on the thigh.

2.8.4.4 Selection of a Sampling Interval (Epoch)

The acceleration signal from an accelerometer is sampled at a certain frequency and then summed and stored at a pre set or user defined real time interval (Chen & Bassett, 2005; Rowlands & Eston, 2007; Trost et al., 2005). This time interval is known as an epoch and the choice of epoch can be a critical decision in the planning process and for data interpretation (Chen & Bassett, 2005). Epochs can range from 1 second to a minute and the epoch selection should depend on the population being studied, the activity being assessed and the amount of memory available (Rowlands et al., 2006). Young children’s
physical activity tends to be short and intermittent (Baquet et al., 2007; Cliff et al., 2009) so a larger epoch length may mean that sporadic bursts of vigorous and very vigorous/hard activities may be missed (Rowlands et al., 2006; Trost et al., 2005; Ward et al., 2005; Welk et al., 2000b). Accelerometry data collected for longer epochs may actually be measuring multiple activities (standing, walking, running) at various intensities (McClain et al., 2008). If the epoch contains a mixture of light and vigorous intensities then the averaged count for the epoch will reflect a more moderate intensity (Chen & Bassett, 2005). McClain et al. (2008) found that a 5 second epoch minimised the error compared to direct observation in a PE class in 10 year olds.

2.8.4.5 Number of Monitoring Days

Differences in weekday and weekend physical activity and inactivity patterns have been reported in young people (Rowlands et al., 2009; Sirard et al., 2008; Trost et al., 2000). This means that a full 7 days of monitoring is required for use with youths (Trost, 2007) with perhaps slightly less for adults. 4 days or more of monitoring is often the criteria recommended for use with children (Corder et al., 2008; Janz et al., 1995; Sirard et al., 2008). Statistical formulas allow investigators to estimate the reliability of differing amounts of monitoring days (Trost et al., 2005). However, while it may be statistically important to collect 12 days of accelerometry data from each participant to get an accurate picture of habitual physical activity, in reality this may not be feasible. There will always be a trade-off between accuracy and not affecting project resources or burdening the participant with the device for too long (Trost et al., 2005) and this burden on participants can affect compliance.

When using a 7 day protocol some participants will not comply and wear the accelerometer for the full 7 days. The next question is what number of days is considered enough to capture the normal physical activity? Mâsse et al. (2005) reported that 3 days of data collection was the criterion used most often. One NHANES data analysis used a minimum of one day (Matthews et al., 2008).

Another factor to consider is reactivity or the “Hawthorne effect”. Reactivity can cause participants to increase their physical activity to above their normal level as they know they are being monitored. Omitting the first day of recording will reduce the impact of reactivity and this is sometimes a data reduction technique employed (Pate et al., 2006).
While some studies have found no evidence of this in adults (Behrens & Dinger, 2007) and children (Ozdoba et al., 2004) or slight increases in children (Mattocks et al., 2008) it could be a plausible error in physical activity measurement.

2.8.4.6 Number of Minutes Monitoring Per Day

The number of minutes recording per day to get an accurate estimate of habitual physical activity would depend on the population of interest. As little as 3 hours a day may provide the same information as 10 hours in children younger than 5 years of age (Cliff et al., 2009). However in children and adults accelerometers are worn during all waking hours and removed at bedtime.

2.8.4.7 What is Considered a Measured Day?

This relates to how many hours the device must be worn for it to be considered a measured day that is sufficient to be considered a measure of habitual physical activity. How much non-wear time can be tolerated before the data is discarded (Mâsse et al., 2005). This is important to report in studies such a data reduction decision as researchers in this area strive for standardisation. Days with less than 10 hours of data recorded have been criteria for elimination (Ekelund et al., 2004; Matthews et al., 2008; Sirard et al., 2008) while Treuth et al. (2004b) considered 800 minutes or more a measured day.

2.8.4.8 Classification of Non-Wear Time

It is normal for participants to remove an accelerometer during bathing or for other reasons at their own volition. Researchers need to identify this time when the device is removed. Studies using the Actigraph monitor differ on how they classify non-wear time. Studies have defined 60 minutes of uninterrupted zero counts (Matthews et al., 2008; Metzger et al., 2008; Troiano et al., 2008), at least 30 minutes of zero counts (Sirard et al., 2008), at least 20 minutes zero counts (Treuth et al., 2004b) and including diary information (Healy et al., 2007, 2008a) and least 10 minutes of consecutive zeros (Andersen et al., 2006; Steele et al., 2009; Trost et al., 2008) as non-wear time. Troiano et al. (2008) made allowances for 1-2 minutes of interruptions of the zero counts (Troiano et al., 2008). A concurrent diary allows participants to simply log these events directly.
Once non-wear time has been defined and identified a decision must be made on how to treat it. This data could be simply deleted (Riddoch et al., 2004). Alternatively, a statistical process called an expected maximisation algorithm has been employed to impute data in place of missing data (Metzger et al., 2008; Pate et al., 2006; Treuth et al., 2007). This is where observed data is used to predict the missing data when the participant has at least one other day of valid data (Catellier et al., 2005). As the variation in protocols are enormous the recommendation is to at least report the decision on how to treat missing data for clarity.

2.8.4.9 Distribution and Collection of Accelerometers

A practical consideration when using accelerometers is how they should be distributed and collected. The obvious strategy in small field based studies is face to face (Treuth et al., 2007; Trost et al., 2005). Using this method detailed instructions can be given to participants and, on collection, the investigators can be sure to receive all the devices back safely. Large scale epidemiology studies like NHANES are now using accelerometry. The devices may be distributed face to face at a central location but returned by registered mail with envelopes and postage supplied by the investigators (Troiano et al., 2008; Trost et al., 2005). Incentives have been used for safe return of the device (Sirard et al., 2008).

2.8.4.10 Promoting Compliance

Many studies report their promotion of compliance but few studies have investigated the effectiveness of differing compliance strategies (Trost et al., 2005). Only one study was identified which investigated how three different compliance strategies would affect the number of days of valid data. Sirard and Slater (2009) found that offering compensation was significantly more successful than completing a daily journal, receiving phone calls or the control condition. On this same point, a study by van Coevering et al. (2005) investigated compliance of young adolescents when using an accelerometer. They found that if seven days of recording is necessary then strategies to improve compliance are necessary. These could include daily reminders, collecting the monitors daily or offering incremental rewards based on the number of days of useable data. Sirard et al. (2008) reported using telephone calls to remind adolescent participants to wear the accelerometers and offering a $5 reward for every day the monitor was worn. Pate et al.
(Pate et al., 2002) gave oral and written instructions on device use. The NHANES study gives full verbal and written instructions on the accelerometer use and offers a remuneration of $40 when the device is returned (NHANES Laboratory Procedure Manual, CDC)

2.8.4.11 Interpretation of the Output

Accelerometers by their nature are based on bodily accelerations but for free living analysis accelerations are too detailed. Outputs from accelerometers will vary depending on the sensors and data processors in the device itself, the capabilities of the software platform and any algorithm applied to the raw accelerations. Outputs can include accelerometer counts, number of steps, estimates of energy expenditure, time spent at the various intensities, time spent in various postures and time spent sleeping.

If accelerometer counts are the output of choice then the next decision is which set of thresholds to use. Often there may be more than one set of appropriate thresholds available. Table 2.12 displays the many thresholds available for the Actigraph and the details of the study- the sample size, population, criterion measure and activities used. Each set of thresholds has their advantages and disadvantages but they all strikingly different (Matthews, 2005). Like the validity and calibration studies that they have been developed from, their success depends on the criterion measure used and what activities the equation were based on. If the calibration is lab based, the thresholds/equation should be cross-validated on an independent sample to see how they perform and translate (Freedson et al., 1998; Welk, 2005). Figure 2.3 graphically compares the thresholds for the Actigraph that are suitable for children. The thresholds by Eston et al. (1998), Treuth et al. (2004) and Puyau et al. (2002) all use different numbers of participants, different age ranges and are based on different activities which all contribute to the variation in threshold values (Freedson et al., 2005). Reilly et al. (2008) went a step further and applied three cutpoints to estimate MVPA and sedentary from free-living data sets. The results in Table 2.11 illustrate the variation in results that can occur depending on the cutpoint/threshold used to interpret the data. Guinohoya et al. (2006) and McClain et al. (2008) both demonstrated the effect that the different Actigraph cutpoints can have on MVPA estimates. Guinohoya et al. concluded that thresholds by Treuth et al. (2004) and Mattocks et al. (2005) may provide the correct threshold for
children. Separately, the 4 MET Freedson cutpoint provided the best comparison to direct observation during a PE class of 10 year old children (McClain et al., 2008).

![Figure 2.3 Accelerometer count thresholds (per minute) for sedentary, moderate and vigorous activity for the ActiGraph from various calibration studies. Reprinted from (Freedson et al., 2005)](image)

Until standardisation of validation techniques occurs or an agreement on the most appropriate thresholds to use, researchers aim to overcome the problem in different ways. Metzger et al. (2008) used an N(sample size)-weighted average of four published thresholds- Freedson et al. (1998), Brage et al. (2003), Yngve et al. (2003) Leenders et al., (2003) for adult data. McClain and colleagues (2008) concluded that the Freedson Actigraph thresholds (Freedson et al., 2005) provided the most comparable results to direct observation but only during a discrete monitoring period of a PE class. It has also been recommended that if appropriate thresholds already exist in the literature then researchers should avoid creating their own and adding to the puzzle (Welk, 2005; Stone et al., 2009).
Table 2.11 Four different thresholds for sedentary and MVPA activity and the difference in time spent in each activity according to the four thresholds. From Reilly et al. (2008)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary (mins)</td>
<td>800</td>
<td>1100</td>
<td>180</td>
<td>N/A</td>
</tr>
<tr>
<td>MVPA (mins)</td>
<td>3200</td>
<td>N/A</td>
<td>3000</td>
<td>630</td>
</tr>
<tr>
<td>MVPA (mins)</td>
<td>28</td>
<td>N/A</td>
<td>41</td>
<td>266</td>
</tr>
</tbody>
</table>

2.8.4.12 Data Reduction Programmes

Data reduction is a challenging aspect to accelerometry research as large amounts of data need to be condensed to manageable, understandable and reportable outputs (Ward et al., 2005). Numerous sets of 7 day accelerometry data present researchers with a challenge. There are a variety of techniques reported in the literature. Research centres have developed their own software for data reduction and make it freely available (MAHUffe, reported in Steele et al. 2009). Studies reported reducing their data using custom made Excel macros (Ekelund et al., 2004; Treuth et al., 2004b), custom made software programmes (Riddoch et al., 2004; Sirard et al., 2008) or using the proprietary software that the manufacturers provide (McClain et al., 2008).

2.8.4.13 Spurious Data

An accelerometer may malfunction and it may be important to identify data that does not seem normal or is outside the range of normal human movement (Mâsse et al., 2005). Metzger et al., (2008) defined spurious data as 10 minutes of continuous identical values to show that the device may have malfunctioned. Mâsse et al. (2005) employed 3 different definitions of spurious data in their algorithms. They used ≥20,000 counts, ≥16,000 counts and 10 minutes of continuous counts >0 and were unable to detect any differences. The problem with identifying spurious data is that researchers must then make the decision on how to treat them-treat them as missing data or replace them with another value (Mâsse et al., 2005).
2.8.4.14 Expressing and Reporting the Data

Expression of the resultant physical activity data will depend on what outcome measures are desired and which will have the most utility (Cliff et al., 2009). Activity counts rather than energy expenditure may be a more suitable way to express and compare a measure of physical activity (Leenders et al., 2000) but estimations of energy expenditure from the raw data are possible if a regression equation has been developed (Troiano, 2006). Since physical activity doesn’t come in an easy to describe packet or measure like dietary data (Trost, 2007) a decision needs to be made on how to quantify the physical activity. Some measurements of physical activity that are useful include METs, energy expenditure, MVPA and steps.

Once the unit of measurement has been decided upon the next step is to express that measure in a meaningful way. Taking steps as an example, steps can be expressed as total steps per day, number of steps at a given intensity level or total time spent stepping per day. The expression of MPA and MVPA is of concern to many researchers as they aim to quantify physical activity which is important to health, which can be compared to guidelines and compared across studies. Taking MVPA as an example, MVPA can be expressed as total time spent in MVPA, MVPA in blocks of 10 minutes or more or MVPA in blocks of 30 minutes or more. The literature (Murphy et al., 2002) and the physical activity recommendations (Haskell et al., 2007) agree that physical activity can be accumulated in blocks of 10 minutes. This would suggest that MVPA should be expressed as bouts of 10 minutes or more. Yet every minute spent in MVPA (discontinuously) is activity that contributes to overall energy balance (Levine et al., 1999; Troiano et al., 2008) and is often the variable reported (Treuth et al., 2004b).

The number and lengths of MVPA bouts as well as total duration of MVPA should be reported (Ward et al., 2005). Time spent at light and inactive levels should also be reported (Matthews, 2005) as time spent in the lower intensities contributes to overall daily energy balance (Levine et al., 1999; Westerterp, 2001). Table 2.13 gives examples of how studies actually report physical activity in more than just one way.
<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>Activities</th>
<th>Criterion</th>
<th>Sed</th>
<th>Light</th>
<th>Mod</th>
<th>Vig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puyau et al., (2002)</td>
<td>6-16yo M/F</td>
<td>Range of light, mod, vig activities</td>
<td>Whole body calorimetry</td>
<td>&lt;800</td>
<td>&lt;3200</td>
<td>&lt;8200</td>
<td>≥8200</td>
</tr>
<tr>
<td>Treuth et al., (2004a)</td>
<td>13-14 yo F</td>
<td>Range of light, mod, vig activities</td>
<td>Indirect calorimetry</td>
<td>&lt;100</td>
<td>101-2999</td>
<td>3000-5200</td>
<td>&gt;5200</td>
</tr>
<tr>
<td>Mattocks et al., (2007)</td>
<td>12yo M/F</td>
<td>Sitting, walking, games</td>
<td>Indirect calorimetry</td>
<td>&lt;2305</td>
<td>2306-6130</td>
<td>&gt;6130</td>
<td></td>
</tr>
<tr>
<td>Freedson et al., (2005)</td>
<td>6-16 yr olds</td>
<td>Composite Regression Equation from Treuth (except cycling) and Puyau data</td>
<td>VO$_2$</td>
<td>&lt;1400</td>
<td>1400-5700</td>
<td>5700-10000</td>
<td></td>
</tr>
</tbody>
</table>

P: Pediatric; A: Adult
<table>
<thead>
<tr>
<th>Authors</th>
<th>Population</th>
<th>Summary Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sirard et al., (2008)</td>
<td>14-19 yrs old</td>
<td>Mean total counts per day</td>
</tr>
<tr>
<td></td>
<td>Descriptive</td>
<td>Time spent in MVPA</td>
</tr>
<tr>
<td></td>
<td>Alternative High School</td>
<td>% of the day spent in MVPA</td>
</tr>
<tr>
<td></td>
<td>School</td>
<td>Light and sedentary time</td>
</tr>
<tr>
<td>Troiano et al., (2008)</td>
<td>6-70+ yrs old</td>
<td>Mean counts per minute</td>
</tr>
<tr>
<td></td>
<td>NHANES</td>
<td>Time spent in MVPA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adherence to recommendations</td>
</tr>
<tr>
<td>Mâsse et al., (2005)</td>
<td>40-70 year olds</td>
<td>Mean counts per minute</td>
</tr>
<tr>
<td></td>
<td>Women on the Move</td>
<td>Mean counts per day</td>
</tr>
<tr>
<td></td>
<td>Study</td>
<td>Time spent in MVPA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adherence to recommendations</td>
</tr>
<tr>
<td>Janz et al., (2005)</td>
<td>5-9 year olds</td>
<td>Counts per minute</td>
</tr>
<tr>
<td></td>
<td>Iowa Bone Study</td>
<td>Time spent in MPA, VPA and inactive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bouts ≥5 minutes</td>
</tr>
</tbody>
</table>

Bouts of physical activity can often include short breaks— for example a participant who is out for a 20 minute walk may stop at traffic lights for 30 seconds. This will break up the physical activity block and may even render it obsolete depending on the data reduction method used. Any data reduction method needs to take into account the normal breaks in physical activity (Mâsse et al., 2005). Table 2.14 shows the difference in minutes of MVPA per day using two methods of expression—total MVPA and bouts of 10 modified 10 minutes (Troiano et al., 2008). The technique chosen to express physical activity data can dramatically affect the results of the study (Mâsse et al., 2005). Overall MVPA is all minutes above the MVPA cutpoint (discontinuous) and bouts of MVPA is 10 consecutive minutes or more above the MVPA cutpoint with allowances for interruptions. Table 2.15 compares three methods of data reporting (also using three different reduction algorithms) on time spent in MVPA.
Table 2.14 Mean minutes per day at moderate to vigorous physical activity for total activity and in modified bouts of 10 minutes or more measured by accelerometry (Troiano et al., 2008)

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th></th>
<th></th>
<th>Females</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6-11</td>
<td>12-15</td>
<td>16-19</td>
<td>6-11</td>
<td>12-15</td>
<td>16-19</td>
</tr>
<tr>
<td>Overall MVPA</td>
<td>95.4</td>
<td>45.3</td>
<td>32.7</td>
<td>75.2</td>
<td>24.6</td>
<td>19.6</td>
</tr>
<tr>
<td>Bouts of MVPA</td>
<td>45.1</td>
<td>18.6</td>
<td>10.9</td>
<td>26.2</td>
<td>7.1</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Table 2.15 Mean minutes (±SD) per day at moderate to vigorous physical activity for total activity and in modified bouts of 10 minutes or more measured by accelerometry (Mâsse et al., 2005)

<table>
<thead>
<tr>
<th></th>
<th>Algorithm 1</th>
<th>Algorithm 2</th>
<th>Algorithm 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall MVPA*</td>
<td>22.8 (14.6)</td>
<td>17.0 (12.4)</td>
<td>22.5 (14.2)</td>
</tr>
<tr>
<td>Bouts of MVPA**</td>
<td>4.1 (7.8)</td>
<td>4.9 (7.9)</td>
<td>3.0 (6.8)</td>
</tr>
</tbody>
</table>

1 allowed for 1 minute of interruption per 10 minute MVPA bout
2 allowed for 2 minutes of interruption per 10 minute MVPA bout
3 allowed for both 0 and 2 minutes of interruption per 10 minute MVPA bout
* Significant difference (p<.05) between algorithm 2 and 1, 3
** Significant difference (p<.05) between algorithm 2 and 3

2.8.4.15 Summary- Building a Protocol

Researchers should strive for clarification and standardisation and important decisions, like those mentioned above, should be reported (Mâsse et al., 2005). Best practice protocols should be developed to ensure consistency and a high standard of research (Welk, 2005). All these points and evidence from the literature should be taken into account when planning, organising and completing an accelerometry based research study (Cliff et al., 2009). The use of the ActivPAL Physical Activity Logger will be discussed under similar headings in section 3.8.4.

2.8.5 Use of Accelerometry in Research Studies

Accelerometry is being utilised in many studies to quantify physical activity and free living energy expenditure levels. The NHANES studies have used accelerometer since 2003 and results have been reported (Metzger et al., 2008; Troiano et al., 2008). It has also been employed to compare physical activity across countries (Riddoch et al., 2004).
Accelerometry is widely used as an outcome measure in interventional studies (Dobbins et al., 2009; Trost et al., 2008) and when looking at weekday and weekend patterns (Dowda et al., 2007; Treuth et al., 2007). It has also been used with prepubertal children (Baquet et al., 2007; Jago et al., 2005) and used as a criterion measure to validate new (Van Coevering et al., 2005) and existing questionnaires. In Ireland, only one study was found that has utilised accelerometry. A 4 day protocol using the RT3 was reported in the methodologies but the results from this study have not been reported or presented to our knowledge (IUNA, 2009).

2.8.6 Measurement of Posture and Inclination

Accelerometry can also provide information on non-movement or sedentary activities (Janz, 2006). Seen as a relatively new scope interest (Hamilton et al., 2009), its need to be measured has been recognised (Westerterp, 1999). This results in the measurement of when the participant is stepping (physical activity) and also the time spent lying, sitting or standing (Levine et al., 2005). These extra layers of lifestyle behaviours are important for a number of reasons. As mentioned in section 2.4.1, sedentary behaviours may have an effect on health outcomes independent of physical activity levels. A certain component of energy expenditure known as non-exercise activity thermogenesis (NEAT) may also play a role in obesity and this again can be separated into NEAT associated with posture and with movement (Levine et al., 2005). The theory is that lower levels of NEAT may negatively impact on a person’s body composition: people with lower levels of NEAT are or may become obese. These light and transitional activities make a contribution to daily energy expenditure (Levine et al., 1999; Westerterp, 2001). Not only that but encouraging sedentary people to increase their light activities and decrease sedentary levels may be as important as increasing higher intensity activity (Treuth et al., 2007).

2.8.7 The ActivPAL Professional™ Physical Activity Logger

The ActivPAL Professional Physical Activity Logger will be described in section 3.6.3.1 and regularly in the proceeding chapters. Briefly, the ActivPAL is a uniaxial accelerometer which directly measures time spent sitting/lying, standing and stepping
from the inclination of the thigh. The ActivPAL has been shown to be an excellent (ICC ≥ .99) measure of step rate at indoor and outdoor walking speeds (Ryan et al., 2006) and the sit to stand transitions during a range of household tasks had strong correlation coefficients Godfrey et al. (2006).

As far as we are aware no study had compared the ActivPAL to indirect calorimetry. This would give a measure of oxygen consumption, a subsequent expression of intensity in Metabolic Equivalents (METs) and also a measure of energy expenditure in kilojoules per minute. Other studies have done similar protocols with other accelerometers and have correlated the outputs. The step count and MET expression is a secondary expression of the acceleration data and the latter being subject to certain (formally stated) errors. The raw acceleration counts are another way to express the physical activity data. Such comparisons are well cited in the literature and examples include Treuth et al., (2004). The technical aspects of this novel device will be discussed in section 3.6.3.1. Like was mentioned in section 2.4.1, having equations and thresholds to predict light and sedentary activities are increasingly important. The ActivPAL can circumnavigate the problems with equations and thresholding as sitting/lying and standing, which is a light activity, are all measured directly.

2.8.8 Summary of Physical Activity Monitoring

It can be concluded that no single device can accurately measure physical activity and the elements that make it multifaceted (Schutz et al., 2001). As well as the validity and reliability of the measure, one must take into account practical issues such as cost, participant cooperation and ease of administration. Principles of design of accelerometry research and analysis differ greatly (Welk, 2005). To advance the understanding of objective physical activity measurement best practice protocols should be followed and important decisions reported on (“Objective monitoring of physical activity: Closing the gaps in the science of accelerometry,” 2005).
2.9 Physical Activity Interventions

Another focus of this thesis is the use of physical activity interventions to promote and increase physical activity. School based interventions will be only focused on and reviewed. A Web of Science search using the keywords: intervention, physical activity, adolescent resulted in 467 articles. Each paper was examined for relevance and 54 were deemed relevant as they involved female populations and were school based in some way. 5 were removed as the full text was inaccessible; one was removed as only dietary outcomes were measured (Lytle et al., 2004) and one because it was not a physical activity intervention (Robbins et al., 2006).

Reviews of the literature have focused on physical activity interventions in children and adolescents (De Meester et al., 2009; Kahn, et al., 2002; Salmon et al., 2007; Stone et al., 1998; Timperio et al., 2004; Watts et al., 2005) with some focusing specifically on school based interventions (Cale & Harris, 2006; Dobbins, et al., 2009; Stone, et al., 1998). Others reviews have focused on interventions from a prevention and treatment of obesity perspective (Boon & Clydesdale, 2005; Clemmens & Hayman, 2004; Luttikhuis et al., 2009; Reilly & McDowell, 2003; Sharma, 2006; Summerbell et al., 2005; Yetter, 2009) and others from a CVD prevention perspective (Resnicow & Robinson, 1997).

2.9.1 Schools as a Place to Promote Health

Schools have been identified as a key setting for changing behaviours and promoting health by many key stakeholders (Centers for Disease & Prevention, 2004; Centers for Disease Control and Prevention, 1997, 2005; Department of Health & Children, 2005). There are a number of reasons for this (Centers for Disease Control and Prevention, 1997; Fox et al., 2004; Kann et al., 1995):

(i) School students are of the age when patterns of physical activity and other health behaviours are being established,
(ii) Students spend the majority of the day in the school setting,
(iii) There is the opportunity for continuous contact,
(iv) Schools often have the equipment and facilities to facilitate physical activity and sports classes,
(v) Schools have more influence on the lives of young people than any other social institution outside of the family,
(vi) Full socioeconomic and ethnic spectrum may be reached.

It could even be said that schools provide the most efficient and cost effective method of improving the health of children (Cameron et al., 2003). Reviews of school based physical activity interventions are summarised and evidence suggests that they can be successful (Kahn et al., 2002). However, methodological issues between interventions remain and targeting the correct population (Kahn et al., 2002) without stigmatising certain young people is key (Ryan et al., 1998).

### 2.9.2 Large Scale Interventions, Follow up and Maintenance

Many interventions reported in the literature involve many schools and many components (Gortmaker, et al., 1999; Gutin et al., 2008; Luepker et al., 1996; Pate, et al., 2007; Simon et al., 2008). These differ from the interventions described in this thesis. Other studies which have been shorter or are based in one location (making them more discreet in nature) can be more comparable to the studies described here (Ambler et al., 1998; Barbeau et al., 2007; Engels et al., 2005; Evans et al., 2009; Lubans & Morgan, 2008).

The main large scale multi-school and multicomponent studies identified are as follows and these will be described in more detail in Table 2.15:

(i) Child and Adolescent Trial for Cardiovascular Health (CATCH)
(ii) Trial of Adolescent Activity in Girls (TAAG)
(iii) Sports Play and Active Recreation for Kids (SPARK)
(iv) Lifestyle Education for Activity Program (LEAP).

There is a dearth of literature from large scale interventions based in Europe. Most of the intervention studies that were identified were based in the United States and results from these studies often cannot translate to European settings (De Meester et al., 2009; Lissau, 2007).
2.9.3 Evidence of the Efficacy of Interventions

The area of school based behavioural and social interventions have been reviewed extensively as described in section 2.9. The outcome measures from interventions come under the headings of lifestyle behaviours (usually either active or sedentary pursuits) and health variables (Dobbins et al., 2009). Lifestyle behaviour changes include increasing physical activity, reducing sedentary time or reducing time spent watching television. Changes in health variables include improving cardiovascular fitness, blood pressure, blood lipid profile and body composition. Reviews by Dobbins et al. (2009) and Kahn et al. (2002) have confirmed the efficacy of some school based interventions on changing these variables. If interventions focus on more than just physical activity, the independent effects of physical activity cannot be established.

Recent intervention studies using obese children and adolescents found that physical training without dietary intervention is effective in enhancing cardiovascular fitness and improving body composition (Barbeau et al., 2007; Gutin et al., 2002; Watts et al., 2004a), blood pressure (McMurray et al., 2002), vascular function (Watts et al., 2004a) and blood lipid profiles (Evans, et al., 2009). Conversely, others found no significant change in BMI (McMurray et al., 2002); body composition (Ambler et al., 1998; Schofield et al., 2005) or physical activity levels (Neumark-Sztainer et al., 2003; Schofield et al., 2005; Webber et al., 2008).

Watts et al. (2005), in a review of the literature, concluded that there are few controlled studies examining the independent effect of exercise in an adolescent population. The same reviewer identified that many studies have not used a matched control group or have not used random assignment thus limiting the strength of their results (Watts et al., 2005).
### Table 2.16 Large scale physical activity interventions from the United States

<table>
<thead>
<tr>
<th>Details</th>
<th>Outcome Measures</th>
<th>Context</th>
<th>Results</th>
<th>Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATCH</td>
<td>N=96 Schools 3rd-6th grade</td>
<td>PE implementation</td>
<td>CATCH PE: changes in PE classes, materials and staff training</td>
<td>5 years after. CATCH-ON SOFIT: MVPA in PE lesson (McKenzie et al., 2003)</td>
</tr>
<tr>
<td>TAAG</td>
<td>2 years</td>
<td>PA levels in PE 7 day accelerometry BMI SOFIT</td>
<td>TAAG PE Behavioural Skills Programs for PA: activity programs outside school Promotional Staff Directed Phase</td>
<td>No change in BMI No change in MVPA (Webber et al., 2008)</td>
</tr>
<tr>
<td>SPARK</td>
<td>4th and 5th grade</td>
<td>Out of School PA-1DPAR Caltrac accelerometer FITNESSGRAM tests, BMI, skinfolds PE Observation SOFIT</td>
<td>Health related PE program Specialist led Teacher led Control 3*30mins per wk Health fitness and skill fitness activities Self management skills</td>
<td>More MVPA and PE classes in specialist led, than teacher led and than control. No change in out of school PA. Some improvements in some fitness tests (Sallis et al., 1997)</td>
</tr>
<tr>
<td>LEAP</td>
<td>N=2111 Girls 9th grade</td>
<td>School Implementation of the program (fidelity, completeness, organisation PA by 3DPAR BMI</td>
<td>Changing personal, social and environmental factors relating to PA Instructional: Changing content and delivery of PE and Health Ed Environmental: Staff support, promotional messages</td>
<td>Girls attending schools that fully implemented LEAP had higher PA levels (Saunders et al., 2006)</td>
</tr>
</tbody>
</table>

PA: Physical Activity; SOFIT: System for Observing Fitness Instruction Time; 3DPAR: 3 Day Physical Activity Recall.
2.9.4 Use of Lifestyle Education in Interventions

Physical activity interventions often include lifestyle or health education which makes the independent effects of physical activity hard to interpret (Kahn et al., 2002). This can take the form of structured education classes and materials or can be presented more informally and may not be fully reported by the authors. Lifestyle education has been used successfully in an adult population in the reduction of Type II diabetes risk (Diabetes Prevention Program Research Group, 2002; Tuomilheto et al., 2001). The effects of lifestyle education interventions alone are mixed with some studies reporting increase physical activity (Taymoori et al., 2008). Much of the successes come from psychological outcomes or self reported physical activity and the long term effects have yet to be fully explored. But the general trend seems to be that lifestyle education alone is not as successful as exercise alone in the short term or as exercise and lifestyle education combined.

As well as structured education lectures, Lubans et al. (2009) utilised promotional material such as newsletters and emails to educate and motive the 14 year old participants. After a 6 month intervention pedometer measured steps increased in the low active participants but there was no change in sedentary or nutritional behaviours (Lubans et al., 2009). McMurray et al. (2002) investigated the effects of an 8 week intervention on blood pressure, body composition and CV fitness of 11-14 year olds. They compared an exercise only group, a health education only group and an exercise and education group. There were no effects on aerobic power or BMI in any group, the sum of skinfolds increased in all treatment groups but the increase was greater in the control group and blood pressure decreased significantly in all groups compared to the control group. The group exposed to health education only showed the smallest effect meaning that lifestyle education alone is not enough to change health parameters (McMurray et al., 2002).

The Lifestyle Education for Activity Program (LEAP), a large scale intervention based on social cognitive theory, aimed to increase self efficacy using positive physical activity experiences within the school environment and PE and health education classes. Multivariable modelling showed that changes in self efficacy had the greatest effect on psychological outcomes and self reported physical activity (Dishman et al., 2004). Physical
activity increased after the 3 year intervention (Saunders et al., 2006) and those in the highest implementing schools also had higher physical activity levels (Pate et al., 2007). Young et al. (2006) utilised a PE based life skills activity intervention. The intervention did increase the amount of time spent in physical activity during the PE classes and reduced sedentary time, it did not change self reported free living MVPA.

2.9.5 Summary on Interventions

The Irish Obesity Taskforce Report (2005) stated that interventions should take place to prevent and treat obesity. Not only should these interventions be put in place they also need to be refined and evaluated in school and community settings as well as clinical settings (Koletzko et al., 2002). If children, even at an early age, separate into high and low physical activity groups and maintain this relative position (see section 2.2.5 on tracking) then interventions before this separation happens are warranted (Kelder et al., 1994). Lifestyle education alone may not be sufficient to increase physical activity levels immediately after the intervention but the long term effects have yet to be fully investigated.

2.10 Literature Review Summary

Evidence relating physical activity and physical fitness to current and future health is inconclusive and no single study has yet to show all the benefits or to prove all the possible links. That said, associations that do exist are positive and the evidence is mounting. Even small modifications in physical activity levels or increases in physical fitness can have an impact on current health parameters and disease risk and health risks in the future (Hasselstrom et al., 2002).
Chapter 3

General Methodology
3.1 Introduction

This chapter describes the general methods that were common to many of the studies completed. The development of an accelerometry protocol is also described in detail following the evidence from the literature presented in section 2.8.4. The development of data reduction, analysis and reporting techniques will be presented in the latter part of this chapter.

3.2 Anthropometric Measurements

3.2.1 Height

Height was measured without shoes using a portable stadiometer (Seca model 214, Seca Ltd, Birmingham, UK). Participants stood with heels together and against the base with arms freely by the side and palms facing the thighs. Shoulders and backside touched the backboard with head up and back straight. The participant inhaled deeply and the headboard gets moved down with enough pressure to compress the hair down to touch the head. Height was measured to the nearest 0.25cm.

3.2.2 Body Mass

Body mass (weight) was assessed to the nearest 0.1kg using a portable electronic scales (Seca model 770, Seca Ltd, Birmingham, UK). Participants wore light shorts, tee-shirt, socks and no shoes. They were instructed to remove jewellery and to empty pockets.

3.2.3 Body Mass Index

Body mass index was calculated from the measures of height and weight by dividing weight (in kilograms) by the square of their height (in meters). Overweight and obesity were classified according to adult BMI standards (WHO, 2004) and UK growth reference charts for children (Cole et al., 1995).
3.2.4 Four Site Skinfold Technique

Percentage body fat was assessed using a four skinfold site protocol (Lohman et al., 1988) by an experienced investigator. These measures took place behind a screen in the main testing area with the investigator always being accompanied by another female. Participants wore a vest top or light tee-shirt. They stood in the anatomical position: standing upright with the head, eyes and toes facing forward, arms by the side and palms facing forward and the legs close together with the feet parallel (Moore & Dalley, 2006). A Harpenden skinfold caliper (Cranlea & Co, Birmingham UK) was used at the following sites: mid-biceps, mid-triceps, sub-scapular and suprailiac. All skinfolds were taken on the right hand side of the body. The investigator ‘pinched’ the skin and subcutaneous tissue 1cm above the particular site with the left hand and placed the arms of the caliper on either side of the pinched tissue with the other. The investigator then released the skinfold so that the caliper remained in position. The thickness was recorded to the nearest 0.25cm. The procedure at each site took 15-20 seconds, but was carried out a total of three times for repeatability and accuracy. The mean of the three measures was used in calculations. The four site measurements were summed, percentage body fat calculated (Resources) and then interpreted (McCarthy et al., 2006).

3.2.4.1 Triceps Skinfold
This skinfold was taken on the midline of the posterior of the arm at the midpoint between the lateral projection of the acromion process of the scapula and the elbow. With the elbow flexed at 90 degrees and the arm hanging loose, this distance was measured and the midpoint marked on the lateral side of the arm.

3.2.4.2 Biceps Skinfold
This skinfold is the vertical fold on the anterior aspect over the belly of the biceps brachii muscle. First, arm circumference is measured and marked at the largest point in line with the triceps mark. The skinfold was grasped on the vertical line joining the anterior border of the acromion process and the centre of the antecubital fossa with the callipers applied at the marked level.
3.2.4.3 Suprailiac Skinfold

This skinfold is at the midaxillary line immediately above the iliac crest. An oblique angled skinfold was grasped just posterior to the midaxillary line following the natural lines of the skin. The skinfold was marked angled slightly downwards and at 45 degrees to the horizontal.

3.2.4.4 Subscapular Skinfold

This skinfold is just inferior to the inferior angle of the scapula. Participants pulled up their vest or tee-shirt and the investigator palpated the scapula to locate the inferior angle. In obese subjects the participant gently placed their arm behind their back to expose the scapula. The skinfold was marked on the diagonal and was taken infero-lateral (at an angle that points outwards and downwards) to this mark.

3.2.5 Waist to Hip Ratio

Using a Seca anthropometric measuring tape (Cranlea & Co, Birmingham, UK) the investigator asked participants to pull up their tee-shirt to above their waist. The narrowest part of the participant’s waist was first measured without the participant taking a breath in. Participants then exposed their hips by moving the waist band of their shorts or trousers and the widest part of the body at the hips was then measured. Waist to hip ratio is computed by dividing the waist measurement by the hip measurement (Clark et al., 2008). Age-specific cut-off points for identifying high trunk fat mass were used (Taylor et al., 2000).

3.3 Blood Pressure

Participants sat quietly and rested for at least 20 minutes before blood pressure was measured and it was always measured before the CV fitness testing portion of the session. Participants sat at a table with their left elbow and forearm resting on the table. An adult and child sized inflatable cuffs were available depending on the participants arm size. An automated sphygmomanometer (Omron model M7, Kyoto, Japan) was placed
on the table with the screen not in view of the participant. An appropriately sized cuff
was placed around their upper arm (in line with the brachial artery), was tightened snugly
and when the monitor was turned on the cuff inflated. In an automated blood pressure
monitor continues to inflate until the brachial artery is occluded. A measurement was
taken once and the cuff deflated. Systolic and diastolic blood pressure was read off the
screen. Blood pressure was measured twice and if the two measures differ it was taken
for a third time. The average of the readings was used for calculations.

3.4 Cardiovascular Fitness Assessment

Cardiovascular fitness was assessed a number of ways over the course of the research.
Which method that was used depended on the cost of transporting the participants to
the lab and what was feasible considering the participants would need to be taken out of
school to attend the lab.

3.4.1 Modified Bruce Protocol

The modified Bruce protocol is a less aggressive version of the standard Bruce protocol
as the increases in speed and gradient are more gradual and there is time allowed for a
warm up. All participants were given full instructions on the protocol individually.
Participants were given a familiarisation session on the treadmill and were encouraged to
walk without holding the hand rails. Heart rate monitors (Polar Electro, Finland) were
fitted on each participant with a chest strap around the chest and the watch on the wrist.
The protocol was as follows: The treadmill was started at 1.6km.h\(^{-1}\) (1 mile.h\(^{-1}\)) on a level
gradient and after 30 seconds the gradient is increased to 1%. Then every 15 seconds
either the speed or the incline or both increases according to the standard protocol.
Heart rate was recorded at the end of each minute and rate of perceived exertion (RPE)
was also recorded. The RPE is where participant’s rate how hard they feel they are
exercising based on the physical sensations that they are feeling. The scale goes from ‘no
exertion at all’ to ‘maximal exertion’ (Borg, 1982). The scale is attached in appendix 11.13
Participants were given verbal encouragement throughout. Tests were terminated when
the participant either (1) reached volitional fatigue, (2) when their heart rate reached 85%
of their age predicted heart rate max or (3) when they reached 17 (‘very hard exertion’) on the RPE scale. Heart rate at each minute and at the termination stage was recorded. The full protocol is found in appendix 11.13.

3.4.2 Modified Bruce with Expired Gas Analysis

This was similar to the above only it followed a slightly different protocol. See appendix 11.13. Each stage was 3 minutes in duration and there were at least 3 stages in each test with the first stage considered a warm up. All participants were given a familiarisation session on the treadmill. During this session the participants were accustomed to walking at different speeds on the treadmill without the use of the handrails. They got accustomed to breathing through the mouthpiece, were instructed about using the emergency stop button and were advised they could terminate the test at any time by giving an agreed signal or by pressing the stop button. This treadmill protocol was combined with the indirect calorimetry protocol described in section 3.5.3.

3.4.3 Twenty Meter Shuttle Run Test

The modified Bruce protocol was successful in a laboratory setting but it was not feasible to bring all participants to the lab for Intervention two. For this reason a field measure of CV fitness was used. The progressive 20 Meter Shuttle Run (20MST) assesses functional capacity and maximal oxygen uptake can be predicted from the results.

Two lines were marked 20 meters apart in the school gym and participants lined up along one line. Speed is controlled by means of a pre-recorded and standardised CD emitting beeps at regular intervals with the pace getting slightly faster at each level. Each level is divided into at least 8 stages. Participants were instructed to jog in a straight line to the opposite end of the 20-meter course and to turn and run the opposite direction in coincidence with the audio beep. They were instructed to pace themselves so as to be at the other end of the 20-metre distance in coincidence with the beep. Participants were required to touch the line at the end of the distance with one foot, turn sharply and safely and run back in the opposite direction. It was stressed to all participants that this is a test
of maximum performance and thus, in order to obtain valid measures, it is essential that subjects are well-motivated and clearly understand the independence of the effort required of them. Investigators stood at each end of the 20-meter distance and gave verbal encouragement and cautioned participants to slow down or speed up as appropriate. Investigators pulled participants from the test if they failed to reach the line by the beeping sound at least twice in a row or if they failed to get to the line by the beep by more than one meter once. The level and stage that each participant ended at was recorded and equations by Léger & Lambert (1982) were used to estimate maximal oxygen uptake or VO$_2$max.

### 3.5 Indirect Calorimetry

Indirect calorimetry was employed during the ActivPAL validation study (Chapters 4 and 5) and when measuring CV fitness in the adolescent population (Chapter 7).

#### 3.5.1 Metabolic Measurement System

Expired gas analysis was collected using an online automated metabolic measurement system (AMIS 2000, Innovision, Odense, Denmark). The metabolic measurement system was calibrated one hour before each test. The flow was calibrated using a standard 3 litre syringe, the gas analyser was calibrated using gases of known concentrations (15% O$_2$, 5% CO$_2$ and nitrogen balance) and temperature, humidity and pressure was inputted. The lab was held at a constant temperature of 18°C.

#### 3.5.2 Measurement of Resting Metabolic Rate

Resting metabolic rate (RMR) was measured before participants began a treadmill protocol. Participants reported to the lab following an overnight fast and having abstained from physical activity the night before and that morning. Participants sat quietly on a chair before the measurement began for at least 10 minutes. Once the measurement was to begin participants lay quietly and supine on a plinth with the head of
the plint at ~10° angle. They lay for 7 minutes in a quiet and darkened room without music or any other sounds. A mouthpiece was placed in the participant’s mouth and a nose clip over the nose for the full 7 minutes. Minute by minute breath samples were taken and averaged every 15 seconds for the last 4 minutes. The last 2 minutes data was downloaded and averaged for RMR calculations.

3.5.3 Measurement of Oxygen Consumption during Exercise

The test began with each participant being given an explanation of the test and what was required of them. They were told about the emergency stop mechanism. Each participant was given their own personal mouthpiece and nose clip and the mouthpiece was attached to the system in front of them by the investigator using disposable gloves. Participants were given a few minutes with the mouthpiece in to get used to breathing with this in and then while using it while walking. Participants then stood with feet at either side of the belt as the treadmill was set up to the required speed and/or incline. One the speed was reached the participant hopped on. Minute by minute results were displayed and recorded online the downloaded and used as appropriate.

3.6 Physical Activity Monitoring

The following section details the various measures of physical activity that were employed with the main focus of accelerometry. The development of a protocol for use and for data reduction, analysis and reporting will also be described.

3.6.1 Habitual Physical Activity Questionnaire

A general assessment of habitual physical activity levels was done using a self report measure developed for use with adolescents (Prochaska et al., 2001). Participants reported the number of days during the past 7, and during a typical week that they had accumulated 60 minutes of moderate to vigorous physical activity (MVPA). This was defined as activity that “increases your heart rate and makes you get out of breath some
of the time” and examples such as basketball and dancing were given. These mean of the
two values resulted in a composite score representing the number of days that the
participant was active for 60 minutes or more.

3.6.2 Self Assessed Physical Activity Checklist

The Self Assessed Physical Activity Checklist (SAPAC) was used in conjunction with the
ActivPAL™ physical activity logger to gain an understanding into participant’s physical
activity levels in one week. The checklist has thirty-eight non PE physical activities
covering all intensities and was modified by Woods et al., (2004) to include Irish sports. It
consists of three sections, i) sport and dance, ii) structured exercise and iii) general
physical activities. The participants indicated if they had participated in a list of activities
within each section. Frequency during the previous 7 days and average duration of the
sessions were also recorded.

3.6.3 Accelerometry

Accelerometry was piloted in Intervention Two (Chapter 6) and was used in full as a 7
day physical activity monitoring in Intervention Three (Chapter 7) and in the Limerick
Physical Activity Study (Chapter 8). The ActivPAL™ and the Actigraph™ GT1M were
used together in a validation and calibration study.

3.6.3.1 The ActivPAL Physical Activity Logger

The ActivPAL™ Professional Physical Activity Monitor (PAL Technologies Ltd,
Glasgow, Scotland) is a single unit uni-axial accelerometer measuring 53 x 35 x 7 mm and
weighing 20 grams. As well as measuring bodily accelerations it identifies episodes of
sitting/lying, standing and stepping. This is known as Intelligent Activity Classification™
and is based on a microelectrical mechanical systems (MEMS) microprocessor. This
allows measurements of both activity and inactivity which is important when working
with sedentary participants. The monitor also records steps and cadence in real time. It
samples at 10Hz and this data is pre-processed and recorded. The ActivPAL has a four
megabyte memory capacity and can record and store data for 7 days and more. It is worn
on the anterior thigh and is attached to the skin directly using a PAL stickie; a hydrogel adhesive pad. It must be removed when bathing, doing water sports or under any circumstances where it may come into contact with liquids.

The device begins to charge once connected to any laptop or PC via an interface. If the computer has the ActivPAL software the devices can be downloaded and initialised. Once the activity session was downloaded it is automatically saved as a .cfg and .pal file. Together they allow the activity session to be viewed directly using the PAL software or the activity session can be saved as Excel files. The raw data can be saved and viewed per hour, per day and per week and is available as:

- Time spent sitting/lying, standing and stepping
- Cadence and total steps
- Number of sit to stand transitions
- An estimate of METs
- Raw counts.

These outputs are described in more details in section 3.7.11.

### 3.6.3.2 Actigraph GT1M

The Actigraph GT1M (Actigraph LLC, Pensacola, FL, USA) is a uniaxial accelerometer measuring 38 x 37 x 18 mm and weighing 27 g. It samples at 30Hz and data is converted into raw counts into the set epoch. The epochs could be set from 1 second to 1 minute but was set at 15 seconds for these studies. It is worn on an elasticated belt or in a pouch which can be attached to the participants down belt and is positioned over the hip. Outputs from the Actigraph software include:

- Raw activity counts,
- Cadence and total step rate,
- Estimates of caloric expenditure based on the Freedson equation,
- Activity graphs.

The latest Actigraph, the triaxial GT3X, includes a function where the two extra dimensions can be ‘turned off’ and it will just function as a uniaxial accelerometer.
3.7 Development of an Accelerometry Protocol

A standard protocol should be developed and agreed upon to move objective physical activity monitoring forward. At the very least important decisions about data reduction and practical issues should be reported on to serve as a guide to future research. To that end, and because at that time no Irish studies reported using free living accelerometry, it was important to develop a protocol for its use. This protocol of good practice shall follow the headings in section 2.8.4 in the literature review.

3.7.1 Selection of a Commercially Available Accelerometer:

Welk (2005) wrote that the goal of the research and the research question needing to be answered should influence the choice of monitor. The ActivPAL physical activity logger was chosen for this research for a number of reasons:

- It was being used by another department within the University and was recommended for use by them.
- The manufacturers were known to give good customer service and technical assistance. This was deemed important as there was no prior experience with recording accelerometry within the department.
- The placement on the thigh was suitable for use with an adolescent female population who may be self conscious about wearing something ‘different’ or ‘obvious’. Unlike the Actigraph models which are worn on the hip on a waistband or the SenseWear Pro Armband over the triceps (Andre et al., 2006), the ActivPAL could be worn discreetly under clothing directly on the skin.
- Direct measure of sedentary activity.

There was no affordable 3-D version of the ActivPAL at the beginning of the research but one was purchased mid way through. A study was completed comparing the 1-D and 3-D ActivPAL in estimating energy expenditure using the same protocol that is described in Chapter 4. It was found that no significant differences existed between the two when measuring free living physical activity (unpublished data).
3.7.2 Number of Accelerometers on Each Participant

Following manufacturers recommendations it was deemed that one device on the thigh would be sufficient to measure adolescent physical activity accurately. It was felt that physical activity from upper body movement would not make a large enough contribution to overall physical activity to warrant an upper body accelerometer.

3.7.3 Placement of the Accelerometer

The ActivPAL placement is on the mid point of the anterior thigh as per manufacturer’s recommendations. Previous research has shown that the actual position on that midline does not significantly alter results (Ryan et al., 2006).

3.7.4 Selection of a Sampling Interval (Epoch)

The ActivPAL epoch is 15 seconds and this was deemed suitable for adolescent physical activity. No further processing needed and the epochs can be easily summed to give counts per minute if desired.

3.7.5 Number of Monitoring Days

In Intervention Two, due to the numbers of ActivPALs available, 5 days of monitoring was employed including both weekend days. For Intervention Three and The Limerick Physical Activity Study, a full 7 days of data were collected. For participant data to be deemed valid and included in the analysis, a minimum of 4 days data was required including one weekend day.
3.7.6 Number of Minutes Monitoring Per Day

The ActivPAL can be worn for 24 hours a day so a limit was not set on the minimum number of minutes they had to be worn.

3.7.7 What is Considered a Measured Day?

The minimum number of recorded minutes for a day to be considered valid was 600 and during typical waking hours (7am-11pm).

3.7.8 Classification of Non-Wear Time

The output from each day was scanned visually for breaks in activity that were 60 minutes or more in duration. Once these were identified, the counts data (epoch results) were analysed. For it to be classified as non-wear time there would be 60 consecutive minutes of 0 counts or 20 consecutive minutes of standing time. Often a person may leave the unit standing up when it is taken off. This time was simply subtracted from the hours spent sitting/lying and from the overall wear time.

3.7.9 Distribution and Collection of Accelerometers

Because the interventional studies were run by the principal investigator the accelerometers were given out and collected face to face on test days or at the intervention classes. In the event that a participant was absent from school or forgot the device prepaid envelopes were supplied. This happened with 6 sets of data that were not returned before a mid term break. A mobile text message was sent in the final study to remind participants to return the accelerometers at the end of the monitored week. Participants forgetting their accelerometer proved to be the most time consuming part of the accelerometry testing protocol. When they forgot the accelerometer or were absent from school the investigator had to take a second trip back to the school to collect them.
3.7.10 Promoting Compliance

Different strategies were employed and modified throughout the interventional studies. In the Intervention Three, participants were given a pack containing detailed written instructions on where to wear the device and how to use them and also some FAQ and troubleshooting. Compliance was a problem at weekend evenings and nights when the participants were going out socialising with friends. They were encouraged to leave the ActivPALs on if at all possible.

The best compliance rate was evident in the Limerick Physical Activity Study (described in 8.3.1). The following strategies were used and can be considered best practice for use with this population:

1. A detailed talk was given to all participants as a group prior to distribution the accelerometers. The topics covered were:
   - Background to the research and why collecting this data is so important,
   - Details of how to wear the device and full demonstration,
   - When the device should not be worn,
   - What exactly is recorded by the ActivPAL and what is not recorded—i.e. the exact activity will not be known and it is not a global positioning system to track them and their location.
   - Advice on keeping the device safe and what to do if it gets lost or broken. Mobile phone numbers of both investigators were given so they could be contacted in the event of loss or damage.
   - Handouts were given with all these specific details and also a small pocket sized handout with general guidelines (appendix 11.5).

2. A sports shop voucher was given to each participant as a reward for a complete set of ActivPAL data.

3. Participants were warned that the investigators would know if they had not worn it.

4. An investigator returned to the school on two other occasions and met with the participants. This was to complete a 7 day physical activity recall questionnaire. While this was not part of the compliance strategy it is hypothesised that this would contribute to compliance as participants knew an investigator would be meeting them and would ask them if they were wearing the accelerometer.
3.7.11 Interpretation of the Output

The ActivPAL output is available in three ways with increasing level of detail and each will be described in the following three sections:

(i) Graphical display of daily activity along with summary variables,
(ii) Excel file for each recorded week with time spent sitting/lying, standing and stepping per 15 second epoch. Also steps and sit to stand transitions per epoch and summary variables for each hour.
(iii) Excel file for a week with the accelerometry counts per 15 second epoch.

3.7.11.1 Graphical Output

The ActivPAL accelerometer data can be displayed graphically: summarised by hour, by day and by week. Examples of this graphical output can be seen in appendix 11.8. These graphs are colour coded with sitting/lying coloured yellow, standing is green and stepping events graded from red to orange with increasing step rate. While this output cannot be used for scientific reporting it was used as an educational and motivational tool. Individual outputs were shown to participants after the pre test to give them a visual portrayal of the amount of time they spent sitting/lying, standing and stepping. The colour coding allowed participants to easily identify times when they were sitting/lying. The absence of the colour red (stepping) tended to shock participants and motivate them. In each output the number of minutes/hours spent in each activity is summarised, and the number of steps taken and sit to stand transitions are listed. Energy expenditure (MET.hr) is estimated using an inbuilt formula-equation 4.1. The overall time spent in each activity is listed alongside the number of steps taken that day.

3.7.11.2 Daily and Weekly Summaries

View data by day and produces an Excel file to summarise each recording day. Time spent sitting/lying, standing and stepping in each 15 second epoch is displayed as is steps for each epoch. An estimation of energy expenditure (in metabolic equivalents) is given based on steps per epoch.
View data by week and produces an Excel file to summarise the recording period by week. This full week summary produces hours and minutes spent sitting/lying, standing and stepping per day and per hour. The number of steps accumulated in each cadence band is also given and this can be used as a crude estimate of minutes at a certain stepping intensity per each recorded hour.

3.7.11.3 Accelerometry Counts per Recording Period

The third level of output is the raw counts (accelerometry counts have been discussed in section 2.8) every 15 seconds. This is based on an algorithm which averages the raw accelerations (which is recorded every $10^{th}$ of a second) into counts. Most studies interpret the raw counts data using thresholds to translate them into energy expenditure or other measures of intensity. Thresholds for the ActivPAL counts had not been created at that time. The development of the thresholds is described in Chapter 5. Table 3.1 are the thresholds that were used for the various intensities to convert ActivPAL counts to METs. ActivPAL data was saved using the ‘save results by epoch’ tab. This produced another Excel file containing the number of counts for every 15 second epoch over the full recording period. This Excel file was the fed into a LabView™ programme. This programme is described in section 3.8.1 in full.

<table>
<thead>
<tr>
<th>Table 3.1 ActivPAL thresholds for female adolescents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
</tr>
<tr>
<td>ActivPAL counts.15 secs$^{-1}$</td>
</tr>
</tbody>
</table>

The most popular way to analyse physical activity levels would be to define intensities using accelerometer counts, known as thresholds, and to report the number of minutes at each count threshold. This has been done extensively in the literature using different population and regression equations have been developed. This had not been done with the ActivPAL accelerometer used in this study. These definitions of intensity using ActivPAL accelerometer counts are described in Chapter 5.
3.7.12 Data Reduction

The method of data reduction depended on what outcome measure of physical activity was required. It was felt that the data reduction using the ActivPAL proprietary software and any functions in Excel did not meet the needs of the research and were not sufficient to give a full picture of meaningful physical activity and sedentary patterns. Data was initially reduced manually. This proved to be very time consuming, was too subjective and had the potential to lead to errors. However the manual method had advantages over an automated approach as rules applied to the data were flexible and could be readily adapted and it allowed the investigator to interrogate the data fully and ‘get familiarised with the potentials that the data had.

In response to the research needs two custom-made automated software programmes were created by two separate collaborators. The development was guided by the investigator and the research needs. A number of versions were created and were tested on sample files to ensure that the automated output matched output derived from manual analysis. These are discussed in detail in section 3.8.2.

3.7.13 Expressing and Reporting the Data

The decision on how to express and report the data depended on how the ActivPAL output was interpreted and what method was used for data reduction. It also depended on the target audience. Some of the outputs that have been used in these studies and reported in presentations, reports and articles:

- Total steps per day,
- Total MVPA per day and bouts of MVPA,
- Total time spent sitting/lying, standing and stepping,
- Sedentary levels and patterns.
3.7.13.1 Physical Activity Levels Using Step Rate

Both the daily and weekly summary deploys steps: steps per epoch, steps per hour and total steps per day. The latter was used to describe physical activity in relation to the step goal.

The steps can also be used to estimate physical activity intensity. The Excel output (summary per week) also gives numbers of steps at each step band for each day and for the recording duration in total (example in Table 3.2). The number of steps was simply divided by the middle of the band to get minutes spent at each step rate per day. For example, 2940 steps were taken at a stepping rate of 100-110 steps per minute. 2940 was divided by 105 steps per minute to get 28. Therefore 28 minutes were spent stepping at a step rate of 105 steps per minute. This was never used as a measure of physical activity.

Table 3.2 Example of accelerometer output showing step band and number of steps.

<table>
<thead>
<tr>
<th>Step Rate Band (steps.min⁻¹)</th>
<th># of Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>'80-90</td>
<td>952</td>
</tr>
<tr>
<td>'90-100</td>
<td>1828</td>
</tr>
<tr>
<td>'100-110</td>
<td>2940</td>
</tr>
<tr>
<td>'110-120</td>
<td>1890</td>
</tr>
<tr>
<td>'120-130</td>
<td>1862</td>
</tr>
</tbody>
</table>

3.7.13.2 Physical Activity Levels Using Accelerometer Counts

Physical activity was quantified in two ways using counts: total time spent at MVPA regardless of the bout length and total time spent at MVPA in bouts of 10 minutes or longer. Due to the low levels of vigorous activity it was decided to combine moderate and vigorous activity together.

When results are saved by epoch an Excel file of counts for every 15 second epoch over the duration of the day is produced. These counts can be then summed for every minute to get counts per minute. Intensity thresholds can then be applied to this data and using the COUNTIF function, the number of epochs or minutes at each intensity level can be analysed. This is called Total MVPA and this is important for measuring the contribution of MVPA to overall EE.
To investigate adherence with current physical activity recommendations, MVPA in bouts of 10 minutes or more must be reported. But physical activity is often discontinuous and any data reduction method needs to take into account the normal breaks in activity. For example, a person may stop at the traffic lights for 30 seconds during a 20 minute walk. This may break up the physical activity block and even render it obsolete depending on the data reduction method used. Section 3.8.1 describes the automated programme that was created for data reduction used to reduce this error. A 10 minute bout of activity which takes into account this natural break in activity is called a modified 10 minute bout and has been used before in the literature (Troiano et al., 2008).

3.7.13.3 Total Physical Activity and Inactivity

Figure 3.1 is taken directly from the ActivPAL output where time spent sitting/lying, standing and stepping is simply summed. This gives an overview of the daily and weekly activity makeup. The estimate of time spent stepping is only useful as an overview as this stepping is at all intensities and is discontinuous. Thus it would not be considered meaningful physical activity as per the ACSM physical activity guidelines (Haskell et al., 2007) and is not used as a measure of health related physical activity here.

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor serial number: AP597713</td>
</tr>
<tr>
<td>Start Time: 09:50:06 11-Sep-07</td>
</tr>
<tr>
<td>Stop Time: 10:46:15 18-Sep-07</td>
</tr>
<tr>
<td>Elapsed Time: 06:56:15 12:50:00s</td>
</tr>
<tr>
<td>Summary by week:</td>
</tr>
<tr>
<td>StartTime</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>17</td>
</tr>
</tbody>
</table>

*Figure 3.1 ActivPAL weekly output file **save summary data **
3.7.13.4 Time Spent Sedentary and Sedentary Patterns

From the various ActivPAL outputs the following outputs were produced and reported on for various papers:

- Total time spent sedentary (sitting/lying),
- Percentage of 24 hours spent sedentary,
- Percentage of waking hours spent sedentary.

An automated programme was also created to garner more outputs and further information on sedentary periods. This will be described further in section 3.8.2.

3.8 Automated Data Reduction and Analysis

To aid with data reduction two automated programmes were created in collaboration with colleagues at the University of Limerick. Each version was tested rigorously before the final version was settled on.

3.8.1 Castnet IV ANL

A Labview™ programme called Castnet IV ANL was created specifically for analysing 7 day ActivPAL data. An ActivPAL output Excel file containing time and raw counts is downloaded and the next steps were followed:

1) The Excel file is saved as a text file and data up to 7am on the second day of recording is removed. This means that the first day of recording is omitted to reduce any impact of reactivity.

2) Each text file is given a short unique name and these names are all typed into another text file.

3) Castnet IV ANL then reads this text file and all the data files named in this text files are analysed. This allows multiple files to be read in and the data can run all night long where necessary.

4) Once the text file is loaded into the programme, the threshold for the intensity of the activity is set and can be modified. The programme interrogates the data for activity over that specified threshold.
5) The bout length also can be altered depending on the length that is of interest. For example if one was interested in 20 minute continuous bouts instead of 10 minutes.

6) As was discussed in section 2.8.4.14 normal physical activity may not be continuous and short breaks can occur. These breaks can be taken into account using the Active Fraction. It allows users to allocate and change the amount of break time that can occur in each activity bout. It was set at 80% for a 10 minute bout—that means that for every 10 minutes of MVPA a 2 minute break is allowed. This has been called a modified 10 minute bout in previous research (Troiano et al., 2008). To be considered a bout beneficial to health only 10% of the counts could drop below the set threshold.

3.8.1.1 Validation

The output from the programme was compared to three sample files which included a wide range of intensities. Castnet ANL accurately measured 100% of the physical activity bouts.
Figure 3.2 Sample screenshot from Castnet IV ANL and explanations of the features

- Bout duration
- Counts threshold
- Percent time spent active per bout
- Location of the text file
- Location where the output is saved
3.8.1.2 Outputs

A sample output from Castnet IV ANL is shown in Figure 3.3. The following data is contained in the output:

- Iteration: The Excel row the bout was first identified at,
- Run: Number of 15 second epochs the bout lasted for,
- Day: Day the bout occurred in,
- Time Active At: Time of day the bout began,
- Active For: Total length of the bout,
- Max Pause: length of the break(s) occurring in the bout (if any).

The data is then summed for each individual day to give total MVPA in modified bouts.

![Sample output file from Castnet IV ANL](image.png)

*Figure 3.3 Sample output file from Castnet IV ANL*
3.8.2 Matlab Programme

A Matlab™ (Version 7.0.1, Mathworks Inc, Natick, MA, USA) programme was created to reduce ActivPAL data in relation to sedentary activities. Accelerometry data was saved as daily summaries in Excel format as described in section 3.7.11.2. This file was fed into the programme and another Excel file with the resultant output was created and saved. The programme scans each 15 second epoch which contains a full 15 seconds of sitting/lying. This sedentary period was only deemed to stop when standing or stepping was identified for greater than 15 seconds. This is called a ‘dynamic period’ in the output. For the purposes of this analysis standing was not considered to be a sedentary activity. This represented the times when the participant was not sedentary and was engaged in light and greater activity (standing and stepping).

Figure 3.4 Screenshot from the Matlab programme
3.8.2.1 Version Development

This automated programme was developed in conjunction with a colleague (Alan Bourke) from the Biomedical Engineering department in the University of Limerick. I informed AB of what the programme should contain, AB wrote the Matlab code and I trialled each one. Its development was informed by the literature and by the research needs. Once a Matlab code was developed, it was tested on a sample of files and the outputs compared. The results were fed back to the developer and he changed the code where necessary. The following are the various codes developed and the problems associated with them.

(1) SedentaryActivityAnalysis_csvwrite.m
Original pilot code
- All Sedentary Activity
- All Dynamic Activity.
Problems: one file at a time could be analysed and this was time consuming.

(2) SedentaryActivityAnalysis_csvwrite_mult.m
Allows analysis of multiple files and records
- All Sedentary Activity
- All Dynamic Activity.
Problems: Only opens .xls files and ActivPAL files are automatically saved as .csv files so it was time consuming to convert each .csv file into .xls.
When the code was used on many files and this data was analyse it was realised that the sedentary data included and averaged includes time when the participant is sleeping at night. This resulted in an inflated mean and stdev sedentary time.

(3) SedentaryActivityAnalysis_csvwrite_csv.m
Opens both .xls and .csv files
The resulting analysis uses three different reduction rules:
- All sedentary activity for the whole day,
- All sedentary activity <3600 seconds. This excludes longer sedentary bouts longer than 2 hours i.e. sleep,
- All dynamic activity.
Problems: Any sedentary activity longer than 2 hours is lost and this could include sleeping during the day.

(4) SedentaryActivityAnalysis_csvwrite_betweenHours
Can be used on multiple .xls and .csv files.

- The resulting analysis uses three different reduction rules:
  - Sedentary activity between the hours of 7am and 11pm only,
  - Sedentary activity <3600 seconds between the hours of 7am and 11pm only. This excluded bouts of sedentary 2 hours and longer but only those that happen in daytime hours as well as night.
  - Dynamic activity

Problems: A limit such as ‘only include sedentary activity between the hours of 7am and 11pm’ seems too stringent. One of the advantages of the ActivPAL is that it can be comfortably worn for 24 hours and does not need to be removed at bedtime. A 24 hour monitoring period also allows a full picture of all activity and patterns and activity that might be done outside of the typical 7am to 11pm monitoring hours. For example at weekends a person may have a different sleep pattern or if a person is working night shifts.

(5) SedentaryActivityAnalysis_ALL_FUNCTION
The same as version four only it included all the sedentary times and its output was formatted clearly in an easier to use .xls file.

3.8.2.2 Validation
There were 3 different ‘rules’ that could be applied to reduce the sedentary data. Sedentary activity less than 2 hours only, sedentary activity between 7am and 11pm only and sedentary activity less than 2 hours between 7a and 11pm. Each version had to be tested against the manual reduction to see which one performs the best to accurately describe sedentary levels without omitting any important information. This was done by taking a random day from each set of participant data and running it though the programme using the 3 ‘rules’. Mean time spent sedentary was the number that was compared between versions. Significant differences between the 3 reduction rules were
highlighted using multiple ANOVA for sedentary methods. It was determined that the reduction method eliminating bouts of sedentary greater than two hours only would be appropriate for this type of data. The final version of the Matlab programme calculated all three.

Table 3.3 Differences between methods of data reduction compared to manual (n=9).

<table>
<thead>
<tr>
<th>Method</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bouts of &lt;3600secs</td>
<td>.086</td>
</tr>
<tr>
<td>Sedentary 7am-11pm</td>
<td>.001**</td>
</tr>
<tr>
<td>Bouts of &lt;3600secs 7am-11pm</td>
<td>.012*</td>
</tr>
</tbody>
</table>

* Significant difference (p<.05) ** Significant difference (p<.01)

3.8.2.3 Outputs

Output data were treated in a similar manner to physical activity data and Castnet IV ANL, data from day one is eliminated as it is not a full 24 hour period. The analysis period starts at 00:00 midnight or 07:00am depending on which ‘rule’ is used. Using the Matlab programme the following outputs were produced and used for analysis and reporting:

- Number of sedentary periods,
- Time of day when each sedentary period occurred,
- Average (±SD) length of each sedentary period in minutes and seconds,
- Maximum and minimum lengths of daily sedentary episodes,
- Length of each break in sedentary activity-called a dynamic period and represents standing and stepping,
- Time of day when each dynamic period occurred in minutes and seconds,
- Average (±SD) length of each dynamic period,
- Maximum and minimum lengths of daily dynamic episodes.
3.9 Interventions

An overview of the school based physical activity interventions are found in this section. Further and more in-depth details are found in Chapters 6 and 7.

3.9.1 Practical Set-up of the School Settings

The procedure for selecting and contacting schools differed with each intervention. In Intervention 1, schools with low PE and physical activity provision were identified and contact details of the PE teacher were sourced from another researcher. They were contacted through mail and then with a follow up phone call. A meeting was arranged with the PE teacher(s) and a timeline and plan was agreed. For Intervention two a previous contact was followed up with and a meeting was arranged with the transition year co-ordinator and PE teacher. These procedures will be described in relation to each individual intervention in chapters 6 and 7.

3.9.2 Intervention Content

The content of the intervention depended on and was informed by a number of factors:

- What was reasonable to teach,
- What teachers were available in the locality and what classes I could teach,
- Irish research on the physical activity preference of adolescent girls (McCallion, 2004),
- What activities this group of adolescent girls wanted from a questionnaire.

In general the majority of the classes were led by the investigator. These classes included aerobic hip hop and salsa dance, toning and circuit classes. Community based instructors were also organised to lead specialised one off classes and to allow participants to experience a wide variety of activities. Pilates, yoga, kick boxing, boxercise, modern, jazz dance and hip hop dancing, gymnastics and aqua aerobics were all covered. Details of community classes were given so the participants could take some classes in their free time. They also exercised during the sessions – warm up, main CV work, resistance
training on the fixed weight machines and toning floor work. The aerobics and dance based classes all had four phases – warm up, main CV phase, toning and flexibility work and cool down stretches. The breakdown of each intervention and the schedule of classes are included in appendices 11.6 and 11.7.

3.9.3 Lifestyle Education Component

The theoretical framework of the lifestyle education was guided by Social Cognitive Theory (SCT) with an emphasis on behavioural change (Bandura, 1986). The behaviour that was aimed to be changed was physical activity and time spent in moderate to vigorous physical activity. Use of SCT followed use by Lubans and Morgan (2008) in the Learning to Enjoy Activity with Friends intervention. The lifestyle education component included ways to increase self-efficacy. Participants were taught goal-setting techniques and self-management strategies, they also identification and discussed overcoming barriers. Outcome expectancy was developed whereby the benefits of physical activity were identification and strategies to make exercise more enjoyable were employed (they chose their own music, could have mobile phones). Outcome expectancy is the primary motivational variable in Social Cognitive Theory and refers to an individual’s desire to achieve positive outcomes and avoid negative consequences (Baranowski et al., 2003). It also includes development of the practical skills necessary for exercising like how to use various pieces of gym equipment and correct weight training techniques. Other interventional studies have utilised SCT successfully (Neumark-Sztainer et al., 2003).

Practical elements of SCT where participants thought about and discussed a number of factors relating to the uptake of a new physical activity included:

1) Goal setting: Participants were asked to set some physical activity goals for the short, medium and long term. A simple short term goal setting sheet was distributed and participants would tick off when they completed a certain task. Goals included getting off the bus a stop earlier, walk to their friends house instead of texting them and dancing around their bedroom to 3 of their favourite songs. The SMARTER (specific, measurable, accountability, realistic, time based, exciting, recorded) goal setting principle was applied to all goals and the group discussed them.
(2) Identification of Barriers to Physical Activity: participants listed and spoke about the barriers which they felt stopped them from doing more or any physical activity. The main barriers and ways to overcome them were discussed as a group and they were dealt with in later classes.

(3) Past, Present and Future Physical Activity: Participants divided a page into three and listed the top three activities that they used to partake in, they currently partake in and that they wished to partake in. Common threads of interest were established and subsequent interest groups were put together.

(4) Basic Physiology: The Sport Science module from the University of Limerick (UL) ‘Science is Fun’ Fair was used in a double class. This module has been used during Science Week, where the University aims to promote science to visiting transition year students to UL. It gave students a basic knowledge of what exercise physiology is and how exercise can affect certain physiological variables. Participants used heart rate monitors, peak flow meters and blood pressure monitors before and after exercise and learned to palpate their pulse. They also tested their hand grip strength. They filled out a basic worksheet and compared results and what affect exercise had.

(5) Identification of local physical activity facilities: Evidence indicates that the availability of commercial physical activity facilities in the local area is associated with increased physical activity in adolescent girls (Dowda et al., 2007). A list of local gyms and sports clubs, pricelists and timetables were circulated.

(6) Feedback from Pre Testing: Participants in the intervention group were given a personal results sheet from the pre test. They were invited to discuss these results in confidence with the investigator. They were also given the graphical output from the ActivPAL for their free living recording. This is discussed in section 3.7.11.1 but briefly it acted as feedback on their physical activity patterns and as a motivational tool. Both the control and intervention groups were given a certificate of completion at the end of the studies with their pre and post test results.
3.10 Statistical Treatment of Data

Data were analysed using Statistical Package for Social Sciences (SPSS version 16.0, SPSS Inc, Chicago, IL, USA). Descriptive statistics were used to express each variable as a mean (± standard deviation), the range and the distributions. Skewness and Kurtosis determined whether the data were parametric and normally distributed. Variables that were not normally distributed were log$_{10}$ transformed. Repeated measures ANOVA were used to analyse results from the interventional studies to investigate any time*group interactions. If a significant interaction was found then paired t-tests were used to compare groups from pre to post test levels. To reduce the potential of a Type II error, A Bonferroni Correction was used where multiple t-test were used. A general linear mixed model was used for modelling ActivPAL outputs against physiological variables to create a prediction equation. The model used takes into account the non-independent nature of the collected data. A model concordance correlation coefficient (CCC) was calculated for each equation to assess its goodness of fit. This CCC is the mixed model version of an $r^2$. Pearson correlations were used to link physical activity and sedentary levels to health variables. If a significant correlation was found multiple regression was used to explore further and potential confounders controlled for.
Chapter 4

Validation of MET Estimates and Step Measurement Using the ActivPAL Physical Activity Logger
4.1 Introduction

Physical activity has been defined as ‘any bodily movement which expends energy’ (Casperson, 1985) and is therefore much more than just sport or structured exercise (Janz, 2006). Valid measurement of physical activity is needed to describe physical activity levels of population groups, investigate the link with disease states and assess the effectiveness of interventions and health promotion techniques (Rowlands & Eston, 2007; Trost et al., 2006).

Many advances in physical activity assessment techniques have occurred in the last decade including the development and refinement of accelerometry-based activity monitors and protocols (Reilly et al., 2008; Rowlands & Eston, 2007; Trost, 2007; Welk, 2002). In recent years there has been an increase in new technologies that offer considerable promise for improving physical activity assessment. The use of MEMS microsensors in newer accelerometry-based devices offer advantages since these sensors are sensitive to both static and dynamic accelerations and this makes it possible to differentiate postures (e.g. sitting/lying, standing).

A challenge in accelerometry-based approaches is that the raw outputs (typically referred to as counts) must be converted into a meaningful and interpretable unit (Troiano, 2006). In most calibration studies, counts are related to oxygen consumption, metabolic equivalent (MET) or caloric expenditure to give a more meaningful and interpretable measure of physical activity intensity (Freedson et al., 2005; Schmitz et al., 2005). However, the outputs from the accelerometer themselves may be useful without having to undertake this calibration stage.

The ActivPAL™ physical activity logger (PAL Technologies Ltd, Glasgow, UK) is an example of a new class of monitoring device. It is an accelerometer which provides a direct output of steps and step rate (cadence) but raw accelerometry counts are easily accessed and downloaded in an Excel file. Information about time spent in different postures—sitting/lying, standing and stepping—are provided in real time. The software also provides an indirect estimate metabolic equivalent (MET) based on steps. This estimate is calculated using an inbuilt equation (equation 1) which is based on step rate rather than counts.
MET, = (1.4*d) + (4 - 1.4) \times (c / 120) \times d

\text{Where } c = \text{cadence (steps per min)}; d = \text{activity duration (in hours)}.

The device has been validated for the determination of static and dynamic activity (Godfrey \textit{et al.}, 2006), measurement of step count in adults at a variety of treadmill and outdoor speeds (Maddocks \textit{et al.}, 2008; Ryan \textit{et al.}, 2006) and for differentiating posture and motion during lifestyle activities (Grant \textit{et al.}, 2006). We are not aware of any studies which have tested the validity of the ActivPAL MET equation. The step rate measure from the ActivPAL has also not been compared to competing technologies.

The aims of this study were to test the validity of the ActivPAL MET equation under controlled conditions using indirect calorimetry as the comparison measure. A secondary aim was to validate the ActivPAL as a measure of step rate which has not been done in young females. The ActivPAL step rate performance will also be compared to the step rate measured by the Actigraph GT1X (Actigraph LLC, Pensacola, Fl, USA). The Actigraph, formally known as the CSA, has been viewed as an accepted standard in accelerometry and activity monitoring (Dencker & Andersen, 2008; Trost \textit{et al.}, 2006) so this is a relevant comparison. The hypotheses (stated as the null hypothesis) are:

\begin{align*}
\text{Ho1} = & \text{METs estimated using the ActivPAL equation will differ significantly from METs measured by indirect calorimetry} \\
\text{Ho2} = & \text{Step rate measured by the ActivPAL will differ significantly from step rate measured by video recorder and by the Actigraph.}
\end{align*}

4.2 Methods

4.2.1 Participants

A convenience sample of 31 healthy, injury free females (aged 18-25) were recruited by word of mouth from the University of Limerick community. An additional 33 females (aged 15-17) involved in an intervention study were also invited to participate in the testing. Written informed consent was obtained from all participants. For participants under 18 years of age, written parental consent was also obtained. A pre test
questionnaire was filled out prior to participation. Approval was granted by the University of Limerick Research Ethics Committee.

4.2.2 Accelerometer

The ActivPAL is a uniaxial accelerometer made up of a single unit measuring 53 x 35 x 7 mm and weighing 20 grams. It is worn on the midline of the anterior thigh and is attached to the skin directly using a hydrogel adhesive pad. The ActivPAL samples bodily accelerations at 10 Hz and can store up to 7 days and more of data in real time. Like most monitors, it must be removed when bathing or when participating in water based activities. A unique function of the ActivPAL is that it distinguishes the incline of the leg to classify periods of time into sitting, standing and stepping. The device has three main outputs for use when investigating free-living activity: determination of posture (sedentary, standing, or stepping), step rate and accelerometry counts, both of which are summed for every 15 second epoch. Each of these outputs are freely available using the proprietary software.

The Actigraph GT1M technicalities have previously been well described (Trost, 2007); briefly it is a uniaxial accelerometer measuring 38 x 37 x 18 mm and weighing 27 g. It samples at 30 Hz and data is converted into sample epochs. It is worn on a belt over the hip and software output includes information such as activity counts, step counts, caloric expenditure, and activity levels.

4.2.3 Testing Protocol

All participants were given a familiarisation session on the treadmill at least 2 days previous to the main test day. During this session the participants were accustomed to walking at different speeds on the treadmill without the use of the handrails, breathing through the mouthpiece, and using the emergency stop button. They were advised they could stop at any time by giving an agreed signal or by pressing the stop button. This was especially important for the adolescent participants, some of whom had not walked on a treadmill before.
On the main test day participants arrived to the University lab in the morning following an overnight fast. After filling out the consent forms and the questionnaire, height and weight were measured as per section 3.2 and body mass index was computed from these two measures. Participants then attached the ActivPAL directly to the midpoint of the midline of the anterior right thigh using a hydrogel pad and an elasticated tube bandage was worn over the device for further stability.

Expired gas analysis was collected using an automated metabolic measurement system (AMIS 2000, Innovision, Odense, Denmark). The metabolic measurement system was calibrated one hour before each test. The flow was calibrated using a standard 3 litre syringe, the gas analyser was calibrated using gases of known concentrations (15% O₂, 5% CO₂ and nitrogen balance) and temperature, humidity and pressure was inputted. The lab was set at a constant temperature of 18°C. Resting metabolic rate (RMR) was measured before participants began the treadmill protocol. Participants lay quietly and supine on a plinth for 7 minutes in a darkened room. A mouthpiece was placed in the participant’s mouth and a nose clip over the nose. Minute by minute breath samples were recorded averaging every 15 seconds with the last 2 minutes averaged for calculations.

Participants then followed a standard locomotor protocol whereby they walked at the following speeds- 3.2km.h⁻¹, 4.8km.h⁻¹, 5.6km.h⁻¹ and 6.4km.h⁻¹ and 7km.h⁻¹ based on previous protocols (Le Masurier & tudor-Locke, 2003). A rest period was given between each speed to allow heart rate to return to resting level. During the same test session a sub-set of participants (n=18) also wore an Actigraph accelerometer. A video camera (Olympus model µ7000, Olympus, UK) to record actual step rate was placed at a right angle to the rear of the treadmill to film the participant’s lower body. A digital timer was displayed in front of the camera to give real time. Each different speed recording was verbally cued at the start of each recording session. The video recorded the last 4 minutes of each walking speed and the mean of the last 2 minutes were used for the step count analysis. Steps were measured to the nearest whole step. Each speed lasted 7 minutes, breath samples were recorded for the last 4 minutes and an average of the last 2 were used in calculations.
4.2.4 Equipment Synchronisation

For data collection, one portable laptop was used to download and initialise both accelerometers. Both accelerometers adopted the time of the laptop and the internal times of the metabolic system, digital timer clock and video camera were synchronised with this laptop. Both accelerometers were initialised approximately 10 minutes before the start of each session.

4.2.5 Data Analysis

- Accelerometry counts were sampled every 15 seconds by both accelerometers. The counts during last minute at each speed summed to give counts per minute for each given speed.
- VO$_2$ (liters.min$^{-1}$) was averaged from the last two minutes at each speed to give an oxygen consumption value for each speed.
- Each participant’s own RMR was used for the calculation of energy expenditure for each speed whereby each participant’s individual RMR was defined as one MET and all values were based this (METind).
- The ActivPAL output includes an estimate of energy expenditure for each 15 second epoch which is based on an internal algorithm (Equation 4.1).
- Step rate was analysed manually from the video recordings by one investigator with steps counted only during the last minute of each speed.
- For both accelerometers step rate was taken from the last minute at each speed. The step rate outputs of both devices are produced by each device’s own proprietary software.

4.2.6 Statistical Analysis

Prior to pooling the data from the two populations (adolescent females and young adult females) t-tests and ANOVAs were used to highlight any possible differences between the two groups. Comparisons between the measures of METs and step rates were done
using t-tests and Bland-Altman plots (Bland & Altman, 1986). SPSS Version 16.0 (SPSS Inc, Chicago, IL) was used for statistical analysis.

4.3 Results

4.3.1 Participant details

The participant characteristics are shown in Table 4.1. Data from two participants were not available due to incorrect initialisation of the ActivPAL accelerometer.

<table>
<thead>
<tr>
<th>Table 4.1 Participant details (n=62)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (± St Dev)</td>
</tr>
<tr>
<td>Age (years, months)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>Body Mass Index (kg/m(^2))</td>
</tr>
</tbody>
</table>

4.3.2 ActivPAL MET Estimates

METs estimated by the ActivPAL were compared to METs measured by indirect calorimetry. The METs from the indirect calorimetry system and METs using the ActivPAL equation were significantly different (p<.001) overall and at each speed. The mean differences between the two measures at each speed are shown in Table 4.2.

As equation 1 is based on step rate it was of interest whether there was a different relationship between measured METs and steps and measured METs and counts. The association between METs and steps was compared to that between METs and counts. In this population of females, the relationship between measured METs and ActivPAL accelerometer counts (r=0.76, p<.001) was higher than the relationship between measured METs and steps (r=0.59, p<.001).
Table 4.2 MET values by speed between actual METs measured from indirect calorimetry and METs estimated from ActivPAL. All differences are significant (p<.001).

<table>
<thead>
<tr>
<th>Speed (km.h(^{-1}))</th>
<th>Measured MET</th>
<th>ActivPAL MET</th>
<th>Mean Difference</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>3.1</td>
<td>3.5</td>
<td>-0.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4.8</td>
<td>3.4</td>
<td>3.6</td>
<td>-0.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>5.6</td>
<td>4.0</td>
<td>3.9</td>
<td>0.1</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>6.4</td>
<td>5.1</td>
<td>4.1</td>
<td>1.0</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>7.0</td>
<td>6.4</td>
<td>4.4</td>
<td>2.0</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

4.3.3 ActivPAL Step Rate

Step rate from both accelerometers were compared to actual step rate from a video analysis. Figure 4.1 presents the means and standard deviations for each device when measuring step rate across all 5 speeds. A significant difference was found at the lowest speed of 3.2km.h\(^{-1}\) only between Actigraph and the video recorded step rate. Actigraph and ActivPAL measured step rate (p<.05). Bland-Altman plots in Figure 2 display the mean, mean difference and 95% limits of agreement between video recorded step rate and ActivPAL measured step rate (Figure 2a) as well as for video recorded step rate and Actigraph step rate (Figure 2b). The 95% limits of agreement between the video recorded steps and ActivPAL were 3.9 to -3.3 steps, mean bias 0.3 steps. Actigraph step rate 95% limits of agreement were 14.8 to -5.8 steps with a mean bias of 2.0 steps. Wider limits of agreement are associated with poorer performance and this could be due to the poorer performance at the lowest speed.
Figure 4.1 Comparison of ActivPAL and Actigraph step rate to video recorded step rate across all speeds. * = significant difference between Actigraph step rate and both the video and ActivPAL measured step rate (p<.05)

Figure 4.2 Bland-Altman plots showing the agreement between (a) ActivPAL and (b) Actigraph step rates and video recorded step rate.
4.4 Discussion

Accelerometry has the potential to enhance the quality and value of physical activity measurement. New physical activity assessment methods require validation against a criterion measure and also against other commonly used devices. This study compared the outputs of the ActivPAL physical activity logger to a measure of intensity and also to the Actigraph, a widely used accelerometry-based device (Rowlands & Eston, 2007).

4.4.1 MET Comparison

The ActivPAL estimate of METs is calculated by an internal algorithm (Equation 4.1) that is based on step rate. The use of step rate in this function would seem inappropriate since it is likely that counts would be more sensitive to changes in intensity than steps as it would allow for more gradation. The association between METs and counts ($r=0.76$) showed a stronger relationship that that between METs and steps ($r=0.59$) in this population of 15 to 25 year old females. This would indicate that prediction equations based on accelerometry counts would be better than the current one based on steps. Equations created for most contemporary accelerometers are based on counts and often include other factors such as gender, age and body mass to enhance energy expenditure estimations (Ekelund et al., 2001; Freedson et al., 2005; Schmitz et al., 2005; Trost et al., 1998).

The correlation coefficients between counts and METs ($r=0.76$) in this study compare favourably to other studies of comparable detail. Brooks et al., (2005) reported values of $r=0.71$ between Actigraph counts and METs during self paced overground walking in adults and Schmitz et al., (2005) reported low correlations ($p=.14$ and .27) between Actigraph counts and kilojoules per minute during brisk walking in adolescents. Freedson et al., (1998) reported $r=0.88$ and Trost et al., (1998) reported $r^2=0.87$ for Actigraph counts during treadmill walking in adults and children respectively. Interpretation from these comparisons requires caution since results can vary depending on the comparison criterion, population tested and methodology used. It can also depend on what the original utility of the device was. The ActivPAL was originally conceived as a monitoring tool for patient populations whose body position, and in particular time spent
sitting/lying, standing and transitioning, was of interest. Measures of sedentary and light activities are of considerable interest in contemporary physical activity research (Pate et al., 2008) so the ability to objectively monitor sedentary behaviours is an important advance (Calabró et al., 2009). The ability to measure sedentary levels without the use of somewhat arbitrary (and variable) threshold methods would be a significant advantage (Freedson et al., 2005). Accelerometers such as the Actigraph provide indirect measures of sedentary behaviour but the ActivPAL methodology provides a more direct measure body position and sedentary time (Matthews et al., 2008) since it measures sedentary levels without the use of thresholds.

A source of error in studies is the variance that can come when defining RMR. Studies often do not measure RMR directly (Trost et al., 2006) or have relied on the generic definition of 3.5ml.kg.min$^{-1}$. However, measured RMR has been found to vary widely in adolescents (Pfeiffer et al., 2006). We sought to eliminate this error by measuring each individual RMR to accurately calculate individualised MET values. Due to operational reasons RMR was only measured for 7 minutes and in certain individuals this may have not been sufficient length to reach a true RMR. The mean measured RMR (3.4±0.6 ml.kg.min$^{-1}$) was not significantly different ($p=.53$) to the generic definition of RMR of 3.5 ml.kg.min$^{-1}$. It appears that in this study, there was no benefit in the use of individualised MET calculations. However, this may be partially explained by the short rest period (7 minutes) used in this study for operational reasons. It is possible that a longer rest period may have resulted in a more representative MET calculation and improved accuracy over use of the generic MET value.

### 4.4.2 Step Rate Measurement

The ActivPAL step rate function has been used as an outcome measure (Ryan et al., 2010) and the Actigraph has been used as a criterion measure of step rate (Le Masurier et al., 2004) so it is critical to ensure that both devices measure step rate accurately. The Actigraph step rate has been shown to be accurate (Le Masurier & Tudor-Locke, 2003) but the ActivPAL clearly performed better at the slowest walking speed. Such slow walking speeds are important constructs to accurately measure in sedentary populations groups whose physical activity may be accumulated at slower walking speeds. It is likely
that the ActivPAL provided better estimates due to the position on the thigh as opposed to the waist.

Step count and cadence are intuitively easier to understand than accelerometry counts, and are simple to use in giving feedback to participants. Whilst simpler, the use of steps alone may in certain circumstances lead to reduced accuracy and loss of precision when collecting data on energy expenditure, particularly at low speeds. We would encourage researchers using this apparatus to explore the use of accelerometry counts in addition to steps.

Walking makes up a significant proportion of the structured physical activity that the population participate in (Livingstone et al., 2008; Lunn et al., 2007). Daily living locomotion also makes a contribution to light activity, often referred to as non-exercise activity thermogenesis or NEAT (Levine et al., 1999). The ActivPAL Physical Activity Logger demonstrated reasonable validity for estimating locomotor intensity; however it may not be appropriate to extrapolate lab based treadmill data to free living situations (Nichols et al., 2001; Trost et al., 2006). Further calibration of the ActivPAL is required and regression equations including a diverse range of free living activities need to be created like has been done in other studies (Treuth et al., 2004a). They also need to be based on accelerations (counts) rather than steps as they would allow for more gradation. This study only included relatively young and healthy females and may not be extrapolated to other groups.

4.5 Conclusions

The ActivPAL internal equation performs reasonably well for estimating energy expenditure in females aged 15-25 but an equation based on counts may be more successful. The correlation between counts and external measures of intensity are similar to previously mentioned studies of other accelerometers. Both the ActivPAL and Actigraph step rate functions were accurate at moderate walking speeds but the ActivPAL performed better at the slowest walking speed. The ActivPAL has an advantage of providing additional information on sedentary levels making it a valuable tool for researchers wanting to quantify both sedentary and ambulatory activities, especially those at lower intensities.
Chapter 5

Development and Cross-Validation of ActivPAL Equations for Predicting Energy Expenditure in Females aged 15-25
5.1 Introduction

Physical activity has many health benefits including improvement of cardiovascular
disease and metabolic syndrome risk factors, body composition and certain cancers
(Bouchard et al., 1994; Ekelund et al., 2009b; Kannel & Sorlie, 1979; Warburton et al.,
2006). Before activity can be further linked to disease states, it must be measured using
accurate, valid and objective means. Many advances in physical activity assessment
techniques have occurred in the last decade (Welk, 2002) but a large challenge in
accelerometry-based approaches is that the raw outputs (counts) must be converted into
a meaningful and interpretable unit (Troiano, 2006). When new monitors are developed
they must be tested and validated to ensure that the outputs are accurate and useful. In
most calibration studies, counts are related to oxygen consumption, metabolic equivalent
(MET) or caloric expenditure to give a more meaningful and interpretable measure of
physical activity intensity. Accelerometry has become one of the most widely used and
widely refined methods (Rowlands & Eston, 2007; Trost, 2007) and as such our
understanding of physical activity is moving forward.

Each commercially available accelerometer has been subject to validation and calibration
studies. These studies have been comprehensively reviewed (Cliff et al., 2009; Matthews,
2005; Rowlands & Eston, 2007). Differences exist between each of the validation and
calibration studies, even within the same accelerometer, due to the setting, the
population, activities, and the metabolic instrumentation used as the criterion measure as
well as the statistical treatment of the data (Matthews, 2005). A treadmill based protocol
has been the traditional means of validating an accelerometer and calibrating its outputs.
Studies have demonstrated that equations developed using treadmill protocols do not
perform well under free living conditions (Guinhouya et al., 2006). In calibrating an
accelerometer it is important to cross-validate any equation created and to check its utility
using an independent data set.
5.1.1 Aims and Hypotheses

The primary aim of this study was to produce energy expenditure estimates that can be translated into intensities of physical activity. This was done by:

1) Calibrating ActivPAL counts to energy expenditure (METs) and to create a prediction equation from treadmill walking for adolescent females.
2) Calibrating ActivPAL counts to energy expenditure (METs) and to create a prediction equation from treadmill walking for adult females.
3) Calibrating ActivPAL counts to METs and to create a prediction equation from free living activities for adult females only.

To investigate the performance of these prediction equations the following were also undertaken:

4) An evaluation of the accuracy of the adult prediction equation by a cross-validation on an independent subset of adult female participants under free-living conditions.
5) An investigate the performance of both adult equations in estimating time spent in MVPA.

The hypotheses (stated as the null hypothesis) of this chapter are:

- Ho1= An equation based on treadmill data will not accurately estimate energy expenditure in adolescent and young adult females.
- Ho2= An equation developed from young female adult data will underestimate when cross-validated on free-living activities and when applied to free-living monitoring.

5.2 Methodology

In summary, 33 adolescent females and 31 young adult females walked on a treadmill over 5 speeds. Each participant wore an ActivPAL physical activity logger while expired gas was collected using an indirect calorimetry system. Mean METs and mean ActivPAL counts at each speed were recorded. Two prediction equations based on this MET-count relationship were created using a mixed model approach—one using adolescent females and the other using adult females. The adult female equation was cross-validated on free
living activity data from a separate population of 12 females. A further prediction equation based on the MET-count relationship was created based on adult female free living data. The utility of both adult equations was then tested on 3 day free living physical activity data sets.

5.2.1 Accelerometer

The ActivPAL Physical Activity Logger is described in section 3.6.3.1.

5.2.2 Treadmill Protocol

Approval was granted by the University of Limerick Research Ethics Committee (PESSREC 44/07). The protocol has been described elsewhere (Chapter 4). Thirty three healthy adolescent females and 31 healthy 18-26 year olds females walked on a treadmill at 5 of 7 different speeds 2.8km.h\(^{-1}\), 3.2km.h\(^{-1}\), 3.8km.h\(^{-1}\), 4.8km.h\(^{-1}\), 5.6km.h\(^{-1}\), 6.4km.h\(^{-1}\) and 7km.h\(^{-1}\). Metabolic data were measured using an automated metabolic measurement system (AMIS 2000, Innovision, Odense, Denmark). The resting metabolic rate of each participant was measured before the test started following an overnight fast. Each participant wore an ActivPAL on the midline of the right thigh. Height, weight and BMI were measured as per section 3.2.

5.2.3 Cross-Validation Protocol

This portion of the study was completed at Iowa State University and approval was granted by Iowa State University Institutional Review Board. The host academic at Iowa State University and one Ph.D. student were responsible for the design, planning, ethics of and recruitment for the study prior to my arrival. I assisted with the testing of the 38 participants with two other Ph.D. students. Data reduction for this portion was done by myself and the two Ph.D. students. This protocol was designed to validate another commercially available physical activity measurement device and was not designed for work with the ActivPAL.
Thirty eight injury free male and females aged 20-35 completed a continuous two hour protocol involving a diverse array of scripted free living activities. The schedule and description of these activities is in Table 5.1 and a further description of each activity is in appendix 11.14.

Oxygen consumption was simultaneously measured by a portable metabolic system (Oxycon Mobile 5.0, Viasys Healthcare Inc, Yorba Linda, CA) to provide criterion values of oxygen uptake. The Oxycon Mobile (OM) is a portable metabolic analyser that allows measurement of oxygen consumption under free-living conditions. In a recent validation study, the OM provided similar metabolic parameters ($VE$, $VO_2$ and $VCO_2$) compared to the Douglas bag method (Hendrickson et al., 2007). Expired gases were collected using face masks (Hans Rudolph INC, Kansas, MO, USA).

The OM portable metabolic system was set up and calibrated following manufacturer recommendations at least 30 minutes before the start of each protocol. The ActivPAL was also initialised 15 minutes before the protocol began. Both devices were synchronised by time. On arrival to the lab, participants were given an information sheet and filled out a pre test health questionnaire and written informed consent. Height was measured to the nearest 0.1cm using a wall mounted Harpenden stadiometer (Harpenden, London, UK) with participants in light clothes and without shoes. Weight was measured to the nearest 0.1kg by electronic scales (Seca 770) with participants in light clothes and without shoes. Participants were then fitted with an ActivPAL on the anterior aspect of the right thigh using a PALstickie and covered with a layer of Medipore™ tape for further security. The portable metabolic system was then put on participants as shown in Figure 5.1. Participants followed the protocol in Table 5.1 continuously and data were stored by OM on a minute by minute basis. On completion of the protocol, data from the OM and ActivPAL were downloaded and saved.
5.2.4 Data Analysis

Data from both metabolic systems and the ActivPAL were stored, downloaded and then processed. As both devices were synchronised by time, exact minute by minute data could be compared. For each equation development, data were averaged over the last 2 minutes of each speed/activity to provide an average minute and 15 second value. For the cross-validation it was necessary to cross-validate the equation on a similar population to the population used in the equation development. Therefore, from the original 38 participants who completed the cross-validation protocol, data from females (n=12) aged 20-29 were selected for use in the cross-validation analysis.
Table 5.1 Schedule of activities and activity duration for the free living protocol

<table>
<thead>
<tr>
<th>#</th>
<th>Activity</th>
<th>Description</th>
<th>Duration (min)</th>
<th>Total time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sitting reading quietly</td>
<td>Participants sat and read without any restrictions or guidelines.</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Free living</td>
<td>Participants walked to the gym at their own preferred pace and getting ready to engage in the next activity.</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Gym Activity (one of 4)</td>
<td>Participants engaged in one of 5 activities at two different intensities-treadmill, elliptical, bike or stepper</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>Free living</td>
<td>Participants walked/stood</td>
<td>10</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>Gym Activity (one of 4)</td>
<td>Participants engaged in a different one of the 4 activities at two different intensities</td>
<td>20</td>
<td>65</td>
</tr>
<tr>
<td>6</td>
<td>Free living</td>
<td>Participants walked/stood and then walking through doors, on different surfaces, walking on stairs and getting ready to engage in road cycling.</td>
<td>10</td>
<td>75</td>
</tr>
<tr>
<td>7</td>
<td>Road Biking</td>
<td>Participants cycled a predetermined outdoor route at their preferred pace.</td>
<td>20</td>
<td>95</td>
</tr>
<tr>
<td>8</td>
<td>Free living (Active Recovery)</td>
<td>Participants walked back to the lab with the bicycle and stood or walking/talking to conclude their trial.</td>
<td>25</td>
<td>120</td>
</tr>
</tbody>
</table>

5.2.5 Statistical Analysis

Descriptive statistics for the participant data were calculated (mean, standard deviation and range). Data were tested for normality using Kolmogorov-Smirnov Test. Statistical assistance was provided by the University Statistical Consulting Unit. The investigator (DH) suggested the appropriate analysis, as informed by the literature, the biostatistician provided the appropriate methods in SPSS and the investigator (DH) ran all the analyses.

Traditional regression is deemed not suitable for this type of data as each participant contributes more than one data point (Welk, 2005). A mixed effect model was used on this data as this allows for both between and within participant heterogeneity (Vonesh et
Details of this are contained in appendix 11.10. Assessing the goodness of fit in these types of models is problematic and there is no universally agreed method for assessing its adequacy. Akaike’s information criterion (AIC) and the Bayesian information criterion (BIC) are reported for comparing the goodness of fit between models. The smaller these values are the better the fit of the equation. These are not ideal as there is no endpoint for a perfect fit (for example an $r^2$ of .8) and may be more useful for selecting a superior model rather than actually reporting its utility (Field, 2009; Orelien, 2002). The model concordance correlation co-efficient has been proposed (Vonesh et al., 1996) and used (Schmitz et al., 2005; Treuth et al., 2004a) as the mixed model version of $r^2$ and is shown in Equation 5.1. This was calculated for each equation.

$$r_c = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)(y_i - \hat{y}_i)}{\sum_{i=1}^{n} (y_i - \bar{y}_i)(y_i - \bar{y}_i) + \sum_{i=1}^{n} (\hat{y}_i - \bar{y}_i)(\hat{y}_i - \bar{y}_i) + N(\bar{y} - \hat{y})^2},$$

[5.1]

Where $\bar{y}$ is the overall mean MET value, $\hat{y}$ is the mean of the fitted values, $y_i$ is the observed MET value, $\hat{y}_i$ is the predicted MET value and $N$ is the number of observations.

Paired t-tests were used to investigate differences between measured METs and METs estimated using the equations for both the whole group and for each participant. Spearman’s correlations were used to compare METs estimated by the new equation and from the criterion measure of indirect calorimetry. All statistical analysis was run using SPSS 16.0 (SPSS Inc, Chicago, IL, USA). Free living MVPA was analysed using a custom made Labview programme called Castnet IV ANL as described in section 3.8.1. Paired sample t-tests were used to check for significant differences between MVPA measured using the treadmill based equation and the free living activity based equation.
5.3 Results

5.3.1 Participant details

The participant details from the three protocols are shown in Table 5.2a and 5.2b. Thirty three adolescents who had two or more data points were included. 29 adults had two or more data points with a further 2 participant’s data missing due to incorrect initialisation of the accelerometer. The 12 adult females aged 20-29 contributed to the adult free-living equation. Participants in the adult treadmill protocol were heavier but not significantly (p>.01) than those in the cross-validation protocol.

5.3.2 Development of a Treadmill Equation

Figure 5.2 shows the scatterplots from the treadmill study and each participant data are in a separate colour for (a) the adolescent group and (b) adult group. Linear regression of these data resulted in traditional r values of 0.67 and 0.77 respectively. However it was a mixed effect model that was more appropriate for these data. A linear mixed model resulted in an adolescent Equation 5.2 and adult Equation 5.4 in Table 5.3. Adding body mass as a covariate did not change either equations ability to predict METs as there was no change in log likelihood, AIC and BIC values. CCC values were then calculated and the adult treadmill equation resulted in an r^2 equivalent of 0.78. This meant that this regression equation was a better fit to the data than the adolescent treadmill and adult free-living equations.
Table 5.2 Participant details (a) and (b)

(a) Adolescent Treadmill Protocol (n=33)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (± SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>15 y 8mo (3mo)</td>
<td>15y 1mo-16y 6mo</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.1 (6.8)</td>
<td>154.1-184.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.8 (10.9)</td>
<td>42.5-96.0</td>
</tr>
<tr>
<td>Body Mass Index (kg/m$^2$)</td>
<td>21.7 (2.7)</td>
<td>16.3-28.1</td>
</tr>
</tbody>
</table>

(b) Adult Treadmill Protocol (n=29)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (± SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22*</td>
<td>18-26</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.0 (5.9)</td>
<td>157.5-177.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.3 (8.4)</td>
<td>54.3-86.5</td>
</tr>
<tr>
<td>Body Mass Index (kg/m$^2$)</td>
<td>24.5 (3.4)</td>
<td>19.8-33.8</td>
</tr>
</tbody>
</table>

Cross-Validation protocol (n=12)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (± SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>24</td>
<td>20-29</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.1 (7.8)</td>
<td>164.3-183</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.3 (10.1)</td>
<td>47.8-74.5</td>
</tr>
<tr>
<td>Body Mass Index (kg/m$^2$)</td>
<td>21.8 (3.2)</td>
<td>17.8-26.9</td>
</tr>
</tbody>
</table>

*significant age difference (p<.001) between participants in the adult treadmill protocol and those in the cross-validation protocol.
5.3.3 Cross-Validation

Attention needs to be given to the overall performance of the new equation during a continuous period of monitoring that is similar to a free living pattern. As free living activity data were only available for adults it was only possible to cross-validate the adult equation. This was done on female participants ages 20-29 only. Equation 5.4 was applied to the cross-validation data set to investigate its performance. Cross-validation with the independent sample revealed a significant correlation of 0.71 (p<.01) between the criterion measure of METs and the new equation estimate of METs. To evaluate variations in associations for each individual participant, correlations based on minute by minute data across the full trial were calculated for each participant (Table 5.4). Correlations ranged from 0.43 to 0.94. However these correlations masked the fact that there is a systematic underestimation by the new equation especially during certain activities in the cross-validation protocol. To evaluate variations due to the activity type, correlations based on each activity were calculated (Table 5.5). To investigate differences in actual MET values between the two measures, mean (±SD) METs were included in Table 5.6. Paired sample t-tests showed a significant difference between the two measures overall and for each participant (p<.01).
Figure 5.3 Bland-Altman plot showing the relationship between Oxycon Mobile energy expenditure (METs) (x-axis) and the difference between Indirect Calorimetry and METs (y-axis) estimated using the Adult Equation (Equation 5.4).

Table 5.3 Adolescent and adult equations predicting METs using counts and counts and body weight and statistics showing the adequacy of the model

<table>
<thead>
<tr>
<th>Equation Type</th>
<th>CCC</th>
<th>SEE</th>
<th>AIC</th>
<th>BIC</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adolescent Treadmill Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MET=1.278+.000539*counts</td>
<td>0.65</td>
<td>.032</td>
<td>267.5</td>
<td>279.0</td>
<td>[5.2]</td>
</tr>
<tr>
<td>MET=1.451609+.000539<em>counts-0.002960</em>BM</td>
<td>.032</td>
<td>269.4</td>
<td>283.8</td>
<td></td>
<td>[5.3]</td>
</tr>
<tr>
<td><strong>Adult Treadmill Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MET=1.069370+.000533*counts</td>
<td>0.78</td>
<td>.104</td>
<td>468.8</td>
<td>480.9</td>
<td>[5.4]</td>
</tr>
<tr>
<td>MET=0.467386+.000533<em>counts+.008973</em>BM</td>
<td>.102</td>
<td>470.7</td>
<td>485.7</td>
<td></td>
<td>[5.5]</td>
</tr>
<tr>
<td><strong>Adult Free Living Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MET=2.19032+.000753*counts</td>
<td>0.62</td>
<td>.740</td>
<td>353.4</td>
<td>353.0</td>
<td>[5.6]</td>
</tr>
<tr>
<td>MET=3.791447+.00075<em>counts-0.026092</em>BM</td>
<td>.754</td>
<td>344.1</td>
<td>356.0</td>
<td></td>
<td>[5.7]</td>
</tr>
</tbody>
</table>

BM: Body Mass

CCC: model concordance correlation coefficient; SEE: Standard Error of the Estimate; AIC: Akaike’s information criterion; BIC: Bayesian information criteria
Table 5.4 Correlations for each Participant between indirect calorimetry measured METs and METs using the new adult equation. This is based on minute by minute comparisons over a 95 minute monitoring period.

<table>
<thead>
<tr>
<th>ID</th>
<th>r*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.82</td>
</tr>
<tr>
<td>4</td>
<td>0.77</td>
</tr>
<tr>
<td>5</td>
<td>0.78</td>
</tr>
<tr>
<td>6</td>
<td>0.77</td>
</tr>
<tr>
<td>12</td>
<td>0.94</td>
</tr>
<tr>
<td>14</td>
<td>0.59</td>
</tr>
<tr>
<td>20</td>
<td>0.74</td>
</tr>
<tr>
<td>23</td>
<td>0.43</td>
</tr>
<tr>
<td>25</td>
<td>0.60</td>
</tr>
<tr>
<td>28</td>
<td>0.67</td>
</tr>
<tr>
<td>31</td>
<td>0.58</td>
</tr>
<tr>
<td>33</td>
<td>0.79</td>
</tr>
</tbody>
</table>

* All are significant at the p<.01 level (2-tailed).

Table 5.5 Correlations for each activity between indirect calorimetry measured METs and METs using the new adult equation.

<table>
<thead>
<tr>
<th>Activity</th>
<th>r*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Living</td>
<td>0.66</td>
</tr>
<tr>
<td>Gym Activity</td>
<td>0.41</td>
</tr>
<tr>
<td>Biking</td>
<td>0.43</td>
</tr>
</tbody>
</table>

* All are significant at the p<.01 level (2-tailed).

Table 5.6 Mean (±SD) METs for indirect calorimetry (IC) and the new equation and the Standard Error of the Estimate of the two measures for each activity.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Counts</th>
<th>IC</th>
<th>New</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Living</td>
<td>1854</td>
<td>3.2 (1.9)</td>
<td>2.1 (1.0)</td>
<td>2.0</td>
</tr>
<tr>
<td>Gym Activity</td>
<td>5705</td>
<td>7.0 (2.5)</td>
<td>4.1 (1.5)</td>
<td>3.6</td>
</tr>
<tr>
<td>Biking</td>
<td>5130</td>
<td>5.9 (1.5)</td>
<td>3.8 (0.9)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

(1985)  (2736)  (1763)

Significant difference between both measures P<.01 (2-tailed)
5.3.4 Comparison of Both Adult Equations

It is important to investigate a monitor's performance for a specific activity or intensity under controlled conditions. This was done in section 5.4.3. The equations also need to be compared under real world conditions. The treadmill based equation (equation 5.4) and free living based equation (equation 5.6) were applied to a set of 3 day free living accelerometry in female adults (n=15). The counts threshold for MVPA (>3METs) according to each equation was applied to the data. The treadmill based equation which had a higher threshold resulted in significantly less minutes spent at MVPA.

Table 5.7 Total minutes spent in moderate to vigorous activity when using the threshold from the adult treadmill equation 5.4 and adult free living equation 5.6.

<table>
<thead>
<tr>
<th>Threshold (counts per 15 secs)</th>
<th>Total MVPA (hours:minutes)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>[5.4] Adult Treadmill Equation 3622</td>
<td>03:13 (± 2:58)</td>
</tr>
<tr>
<td>[5.6] Adult Free Living Equation 1075</td>
<td>05:16 (± 3:55)</td>
</tr>
</tbody>
</table>

* Significant difference (p<.001)

5.4 Discussion

We have developed a mixed model regression equation to estimate energy expenditure from ActivPAL counts in adolescent females and also developed and cross-validated the same in young adult females. These were both based on a standard treadmill protocol. We have also created a regression equation based on free living activities for adult females. To compare the performance of both adult equations we used them on 3-day accelerometry data sets and compared time spent in MVPA using both.

5.4.1 Adolescent and Adult Equations

From the model CCC of 0.78, the adult model was a good fit. This fit can be compared to the results from other treadmill (Hendelman et al., 2000; Melanson & Freedson, 1995) and free living studies (Brooks et al., 2005) in adults. The equation was then applied to
free-living situations and the significant mean difference of the equation when predicting METs (Table 5.6) would suggest that the model may only be useful when looking at total physical activity. The equation can be used to distinguish between light and moderate physical activity and can identify moderate physical activity adequately. The equation is less effective at estimating total EE where it tends to underestimate. The same was said for the performance of ActivPAL inbuilt equation (Chapter 4) which was based on steps. This is similar to a results reported by Hendelman et al. (2000) who found that while the correlation between counts and VO\textsubscript{2} was strong, the equations underestimated for free-living activities. The activities used by these researchers were household tasks which included much upper body movement. In the same way that we would not expect the ActivPAL to detect the changes in grade of a treadmill or the resistance of the elliptical machine, Hendelman and colleagues concluded that the accelerometer did not detect upper body energy cost.

The ActivPALS own equation has been shown to significantly underestimate METs for females and this new equation does not do better. While both the ActivPAL inbuilt equation and this new adult equation showed significant differences compared to the criterion measure (p<.001) there was no significant difference between the inbuilt equation based on steps and our new equation based on counts (p=.31). A Bland-Altman plot, including limits of agreement and mean bias, is displayed in Figure 5.4 to illustrate this.

![Bland-Altman plot showing the agreement between energy expenditure (METs) estimated from the ActivPAL inbuilt equation and METs estimated using the Adult Equation (equation 5.4). Upper and Lower Limits of Agreement: 2.4 and -2.3 respectively; Mean Bias: 0.03.](image-url)
The extra utility of having a threshold based on counts instead of steps is that counts allows for more gradation. For example, moderate physical activity using steps is 23-35 steps per 15 seconds (data not shown) whereas we define the moderate physical activity threshold for counts as 3195-8760. Using counts means it is more sensitive to change. Walking one step slower would have more of an effect than walking at one count slower. There are limitations to this type of cross-validation. The range of activities in the cross-validation may have been too extreme to imagine that a treadmill based equation would pick up. It would be more appropriate to just cross-validate a treadmill equation on walking activities rather than ones that also included stepper and elliptical (gym activities). However, excluding the gym activities from the already small number of females would have depleted the data even more. Ideally, the treadmill based equation would be for males and females and could then be cross-validated on the whole free-living sample (n=38) for just walking activities. This free-living protocol was planned prior to my arrival at Iowa State University and I had no control over changing it or including different activities.

5.4.2 Comparison to Other Results

Other studies have reported that monitors overestimate EE for treadmill activities but underestimate it for free living activities (Welk et al., 2000a). The free living protocol included gym activities such as the elliptical and the stepper machines which would not be expected to hold a strong relationship between counts and METs. Trueth et al. (2004) reported that the Actigraph (model 7164) counts and MET score showed a poor relationship for outdoor biking. Using their equation, outdoor biking had a MET score of 2.6 METs while the measured MET score using the criterion of indirect calorimetry was actually 5.9 METs. This trend of underestimation was seen in our data also but to a lesser extent. Using the adult equation (Equation 5.4) outdoor biking had a MET score of 3.8 METs while the measured MET score using the criterion of indirect calorimetry was actually 5.9 METs (Table 5.6). This could be explained by the placement of the ActivPAL on the thigh which would overcome some of the expected underestimation during biking compared to be hip mounted Actigraph.
5.4.3 Treadmill versus Free Living Calibrations

In section 5.3.4 we compared results using two thresholds from two different equations—one based on treadmill walking and the other based on free living walking and gym activities. Other studies and researchers have noted the difference between thresholds based on treadmill data and free living data even for the same population and accelerometer (Freedson et al., 2005; Matthews, 2005; McClain et al., 2008). Some of these examples are presented in section 2.8.3.2 and support the notion that the performance of treadmill equations are limited when applied to free living activities and settings.

When the equation based on treadmill data and the equation based on free living data were applied to the same 3 day accelerometry data, time spent in MVPA was significantly different. This highlights the discrepancies between the two calibration techniques. Similar results have been reported by Guinhouya et al. (2006), McClain et al. (2008) and Reilly et al. (2008) between various Actigraph thresholds in children. It is unclear whether a treadmill or free living activity protocol is best but its eventual application should inform which is most appropriate to use. Equations which are based on treadmill data were continuously used to measure free living habitual physical activity. It is agreed that cutpoints from a treadmill study and that from a non-treadmill or free living study differ extremely (Freedson et al., 2005; Reilly et al., 2008) as there is too much variance in the activities that are included. When just free living walking was included in the mixed model it showed a slight change (data in appendix 11.15). There is much variation in Actigraph counts even at the same speeds (Ekelund et al., 2003) reflecting age, economy and biomechanical differences. The range of ActivPAL counts at each speed is tabulated in appendix 11.15. There are agreed limitations to applying treadmill walking data to free living walking. There is also higher (Yngve et al., 2003) and lower (Nichols et al., 2000) counts for overground walking compared with treadmill walking. This has not been assessed using the ActivPAL at present.

The limitations of this study were that the equation was cross-validated on a small sample. As there was no measure of CV fitness to control for any differences in physical fitness between the two groupings it was felt that the two groups differed. Anecdotally the fitness levels of both groups were different with the cross-validation group possibly
being fitter. While it is essential that cross-validation occurs in an independent sample, a sample homogenous to the original population would be desirable. Future work based on the results here and based on the wealth of data collected would be a full cross-validation of the adolescent equation in free-living walking and the development of a new equation using these activities. This would allow further investigation of the utility of the inbuilt ActivPAL to measure all intensities of activity. As described in Chapter 4, this equation is based on steps and we hypothesised that an equation based on counts would be of better value. However, as was seen in Figure 5.4 there was no significant difference in estimating energy expenditure between the two equations. We would hypothesis still that an equation based on counts would be more sensitive to MVPA as measured in modified 10-minute bouts. These bouts allow for a break during each continuous activity period.

5.5 Conclusion

In conclusion, we found that the relationship between energy expenditure and accelerometry outputs is highly dependent on the activity that is performed. Like other studies, we found that it was inappropriate to apply treadmill based equations to certain free-living activities as it resulted in an underestimation of energy expenditure. A mixed model approach was used to model the energy expenditure and counts relationship. This has been recommended as an alternative to linear regression so this may serve as groundwork for future validation studies on the ActivPAL.
Chapter 6

Physical Activity Intervention and Accelerometry in Irish Adolescent Females: A Pilot Study
6.1 Introduction

The National Obesity Taskforce Report (2005) stated that “schools should develop increasing opportunities for physical activity that are inclusive and that are appropriate to age, gender and ability such as those that concentrate on increasing physical activity among teenage girls” (Obesity, The Policy Challenges, 2005: p89). This was in response to claims that not only were Irish youth less physically active than previous generations but that adolescent females were less physically active than their male peers (Kelleher et al., 1999; Kelleher et al., 2003; Riddoch et al., 1991; Woods et al., 2004).

The effectiveness of school based physical activity interventions in increasing physical activity levels and improving body composition has been thoroughly reviewed (Kahn et al., 2002; Stone et al., 1998; Watts et al., 2005). The approach has varied between physical education (PE) based intervention (McKenzie et al., 1996), whole school approaches (Saunders et al., 2006) and after school programs (Kelder et al., 2005; Story et al., 2003; Trost et al., 2008). No clear consensus has been drawn on the most appropriate or effective intervention strategy to follow. However, reviewers recommend a focus on girls, the use of objective measures of physical activity and a focus on decreasing sedentary behaviours as well as increasing physical activity (Salmon et al., 2007; Stone et al., 1998; Timperio et al., 2004).

Based on this evidence it was decided to run a physical activity intervention for adolescent females. School based interventions are most suited for use with children and adolescents. School is a cost-effective place for interventions (Cameron et al., 2003) as space and equipment is available, there is opportunity for continuous contact and school has the most impact on a young person’s life outside of the family (Centers for Disease Control and Prevention, 1997; Fox et al., 2004; Kann et al., 1995).

6.2 Aims and Hypotheses

The aims of this study were two fold. First was to pilot two school based physical activity interventions to target adolescent females- an after school intervention (Intervention one) and a school timetabled intervention (Intervention two). The second aim was to use
recording accelerometry to objectively measure physical activity levels and to begin the development of a protocol that could be used in future research. The hypotheses (stated as the null hypothesis) of this chapter are:

Ho1= A physical activity intervention will not increase participants levels of MVPA  
Ho2= A physical activity intervention will not positively change participants health parameters.

6.3 Choosing the Schools

Schools with low PE and physical activity provision would benefit from a novel opportunity for physical activity. Sohun and MacDonncha (2001) evaluated the Second Level schools in the locality for their PE and physical activity provision. This included documenting sport infrastructure, equipment, staffing and time spent on PE. This evaluation was used to highlighted suitable schools (ones with low provision) and three were contacted with an expression of interest form. The minimum requirement was to have access to a gym, sports hall or a classroom large enough for physical activity classes. Two schools responded and teachers from both were met. One school was chosen for practical reasons for the initial After School intervention (Intervention one) in September 2006. For Intervention two, which began in September 2007, a meeting with a second school was set up in May 2007. This was prior to the end of school year so that students could be approached about taking part in the intervention before the timetable was made out during the summer months.

6.4 Intervention One- An After School Intervention

Intervention one began in Sept 2006 and was co-ordinated with the PE teacher and Physical Activity Co-ordinator of the school. The PE teacher allowed the initial contact with students and he played no further role in the intervention. The Physical Activity Co-ordinator was the chaperone when the participants visited the University for pre and post testing. He also opened the sports hall and was the point of contact between the participants and the investigator. Deirdre Harrington ran all the activity classes, organised
the testing sessions and co-ordinated the testing sessions. She was assisted by two trained undergraduate students during the pre and post testing.

6.4.1 Ethics Committee Approval

Approval was granted by the University of Limerick Research Ethics Committee (ULREC 06/59). Study procedures were approved by the school principal. All potential participants were given a participant information sheet, a parent/carer information sheet, a participant consent form and a parent/carer consent from. To be eligible for the initial screening students were required to return both consent forms fully signed. Those not giving consent were ineligible for the screening tests. The participants who were eligible for the study were then given a new set of documents depending on which group they were assigned to- a participant information sheet, a parent/carer information sheet, a participant consent form and a parent/carer consent from. Participants who did not receive parental consent at this stage were not permitted to participate in the study or any of the exercise classes but they were given a list of local gyms and exercise classes where they could access similar activities.

6.4.2 Identification of Participants (Screening)

The aim was to identify a group of adolescent females who did not meet current physical activity guidelines (Pate et al., 1995) and/or were at risk of becoming overweight or obese by age 18 (Cole et al., 2000). All students from 4th to 6th year (ages 15-18) were invited to participate in the initial screening and those who returned a participant consent form and a parent/guardian consent form underwent testing. This simply involved a Habitual Physical Activity Questionnaire developed for use with adolescents as per section 3.6.1. Also height and weight was measured as per section 3.2 and body mass index (BMI) was computed from these two measures by dividing weight (in kilograms) by the square of their height (in meters).

31 students completed the screening phase and they were all deemed suitable for the intervention. 22 students agreed to be randomly assigned to either the control or
intervention groups within the same school. 5 participants did not receive parental consent, 3 participants declined as they were in their final year of school and were time constrained because of exams and 2 withdrew because they were assigned to the control group.

6.4.3 Pre and Post Testing

All participants reported to the Department of Physical Education and Sport Sciences lab in groups of 8 after school. They were supervised in a nearby classroom where they did homework or watched a DVD. Parameters measured were height, weight and BMI and a 4 site skinfold protocol as per section 3.2. Cardiovascular (CV) Fitness Test was measured using the treadmill based Modified Bruce protocol as per section 3.4.1.

6.4.4 Intervention

The 12 week aerobics intervention ran over 15 weeks with 3 weeks break in between due to Midterm and Christmas holidays. Pre and post testing lasted for 1 week at either side of the intervention. The intervention classes took place twice a week for 40 minutes after school. Participants reported to the sports hall (and subsequently the canteen) and their attendance was taken. Each class was aerobic dance class and was broken into a warm up, a main CV phase, a resistance and toning phase and a cool down. Beginners and experienced were catered for and adaptations and progressions were demonstrated for all exercises and moves. Heart rate was taken manually by a different student by palpation of the radial pulse. This took place at the end of each phase to ensure that the intensity was not too low (or too high). The classes began in the sports hall but after approximately 7 weeks the classes were then moved to their canteen space due to other extra curricular sports encroaching on the sports hall timetable. The lead investigator taught 100% of the activity classes.
6.4.5 Intervention One: Results

Participant details at baseline are included in Table 6.1. From the habitual physical activity questionnaire a composite score for physical activity was calculated. The number of days that participants were physically active in the previous 7 days and the number of days that they were usually active were summed and divided by two to get a composite physical activity score. The number of days that participants reported being active is presented in Figure 6.1. Those classed as underweight, normal weight, overweight and obese are tabulated in Table 6.2 using the adult definition of obesity (WHO, 2004). BMI cut off points and growth reference charts for those under 18 (Cole et al., 1995; 2000) were also used to predict those who would be classed as overweight or obese by age 18 using their current BMI. Twenty two participants completed the pre test and their data are presented in Table 6.3. Nine intervention and 4 control group participants completed the post test. The low numbers completing the whole intervention and the post test were too low to be able to draw any statistical conclusions.

Table 6.1 Participant (n=31) details at baseline

<table>
<thead>
<tr>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean 16 yr 8 mo</td>
<td>162.1</td>
<td>66.0</td>
<td>25.1</td>
</tr>
<tr>
<td>StDev ± 11 mo</td>
<td>± 6.1</td>
<td>± 10.2</td>
<td>± 4.0</td>
</tr>
</tbody>
</table>

Table 6.2 Number of participants classed in each of the body weight categories at baseline (n=31).

<table>
<thead>
<tr>
<th></th>
<th>Underweight</th>
<th>Normal</th>
<th>Overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO</td>
<td>1</td>
<td>15</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>IOTF</td>
<td>N/A</td>
<td>13</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>UK Growth Reference Charts</td>
<td>N/A</td>
<td>15</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>
Table 6.3 Pre test results for the group as a whole (n=22)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>16yr 3mo</td>
<td>±10 mo</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.0</td>
<td>±6.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>62.6</td>
<td>±9.3</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>23.9</td>
<td>±3.7</td>
</tr>
<tr>
<td>Biceps (mm)</td>
<td>15.6</td>
<td>6.5</td>
</tr>
<tr>
<td>Triceps (mm)</td>
<td>20.2</td>
<td>8.4</td>
</tr>
<tr>
<td>Subscap (mm)</td>
<td>14.3</td>
<td>6.1</td>
</tr>
<tr>
<td>Suprailiac (mm)</td>
<td>16.5</td>
<td>7.1</td>
</tr>
<tr>
<td>Sum Skinfolds (mm)</td>
<td>64.9</td>
<td>24.8</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>20.9</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Figure 6.1 Self reported habitual physical activity levels of participants at pre test level, calculated from a composite score of ‘how many days active in the last 7 days’ and ‘how many days active usually’. Numbers on the graph represent percentage of participants.
6.5 Intervention Two- School Timetabled Intervention

Following the experiences of Intervention One a second intervention was planned for the school year beginning in September 2007. Attendance was an issue with Intervention One so it was felt a timetabled based intervention would work better. It was run in a different school and was specifically for Transition Year (TY) students. TY is a year between junior and senior cycles where students can participate in a range of non-academic classes, go on work placement and there is a focus on personal development. Students are usually aged 15-17 in this year. There are no exams commitments for the students and the timetable would be more flexible than that of the junior and senior cycle years.

The programme began in Sept 2007 and was co-ordinated with the TY co-ordinator and the PE teacher of the school. The TY co-ordinator allowed the initial contact with students and he played no further role in the intervention. The PE teacher organised for the participants to be excused for pre and post testing or for any gym visits. She also opened the sports hall, took attendance and was the disciplinarian. She was not the point of contact between the participants and the investigator as the investigator had each participant’s mobile phone number and visa versa. The investigator (DH) ran the majority (∼75%) of the activity classes, organised the testing sessions, co-ordinated the testing sessions and attended each activity class regardless of whether she was teaching it or not. A breakdown of this is included in appendix 11.6.

6.5.1 Identification of Participants

Participating students were identified prior to the end of the preceding school term. An information evening on all subjects available in TY was held in the school and students were approached informally by the PE teacher and the TY co-ordinator informally. Both teachers were briefed that they should only approach students who were not on any sports teams (in or out of school), did not partake in extra-curricular sports or activities and possibly did not take an active part in PE lessons in the previous 3 months. All these names were recorded (n=26) and were divided at random into an intervention (n=18)
and control (n=18) groups. Approval was granted by the University of Limerick Research Ethics Committee (ULREC 07/38).

6.5.2 Pre and Post Testing

Pre testing happened in the first week of September with field based testing lasting two classes. Pre and post testing was changed from lab to field to lab testing. This was due to costs and the extra time it took bussing participants from the school to the lab and back again. Height, weight, BMI and 4 site skinfolds were as per the after school intervention. CV Fitness Test: CV fitness was estimated using the 20 Meter Shuttle Run (20MST), a field based test, as per section 3.4.3.

6.5.3 Measuring Physical Activity Levels

5 day accelerometry was used to measure habitual physical activity using the ActivPAL physical activity logger (PAL Technologies Ltd, Glasgow, Scotland). This has been described in section 3.6.3.1. Accelerometry measures ran over 3 weeks at pre test level prior to the beginning of the actual intervention classes. There were limited devices available so 8 people at most could be tested per week. The control group accelerometry took place after all intervention participants were tested.

Participants were given a pack with their ActivPAL. Each pack contained spare PALstickies, MediporeTM medical tape to envelope the device when on the leg, detailed written instructions and also some FAQ and troubleshooting. A physical activity diary where students would log the times and durations when they removed the device was also included. It was hypothesised that peer pressure and social norms could affect the compliance with an accelerometry protocol as participants do not want to be seen wearing anything deemed different or uncool when socialising. In recognition of this, participants were encouraged to leave the accelerometers on if possible but to record in the diary if it was taken off. The ActivPALS were either collected straight from the student, the student left them at the school reception for collection or they were posted
back to the investigator. Once collected the device was connected to a laptop and the data were downloaded and the device recharged.

### 6.5.4 Intervention

It was important that this timetabled physical activity intervention did not clash with, take over from, be instead of or encroach on the normal PE Classes. This was to ensure that the control and intervention groups both got their standard timetabled PE class and that the intervention group got this extra physical activity on top of that. The class was timetabled twice a week for transition years- one 40 minute class and a double class of 80 minutes. The first 3 weeks saw the single class being used for lifestyle education classroom based work and the 80 minutes for the physical activity classes. Intervention one was after school based so attendance was not mandatory. In this intervention all classes were timetabled and attendance was compulsory. Attendance was taken of all who arrived and those who attended but did not partake in the activity for whatever reason were also noted. Unlike the pilot study the activity classes all took place in the gym and were never moved elsewhere when something ‘more important’ came up. A schedule of the intervention classes can be found in appendix 11.6.

The content of the intervention depended on and was informed by a number of factors: (1) what was reasonable to teach, (2) what teachers were available in the locality and what classes the investigator could teach herself, (3) what Irish research has said that adolescent girls like to take part in (McCallion, 2004) and (4) what activities this group of adolescent girls wanted. In all aerobic dance, hip hop dance, boxercise, kick boxing, total tone, circuits and playground games were all taught. The aerobics and dance based classes all had four phases – warm up, main CV phase, toning and flexibility work and cool down stretches. Intensity was monitored using self-palpation of wrist pulse. Participants were also brought to a local gym every 2 months. The visit was designed to induct participants to the equipment and familiarise themselves with a gym setup. They also exercised in each session – warm up, main CV work, resistance training on the fixed weight machines and toning floor work. As part of the goal setting task, five members of the intervention group also signed up for a local fun run. They trained for 3 weeks before the event doing mostly walking and building up to jogging. All five completed the course
in less than 90 minutes. As a further challenge, these 5 participants also signed up to do the Flora Ladies Mini Marathon in Dublin, which happened in the Summer 2008, and were given a walking/jogging training program to follow.

6.5.5 Data and Statistical Analysis

Descriptive statistics, repeated measures ANOVA and t-tests were all run using SPSS 15.0. Repeated measures ANOVA was used to investigate any time*group effect. Where significance was highlighted, a paired t-test (Bonferroni correction) was used to highlight which group had changed.

6.5.6 Intervention Two-Results

Descriptive data for all participants are included in Table 3 for both groups and also from pre to post tests. Time*group interactions showed that estimated cardiovascular fitness of the intervention group increased significantly (p<.001) whilst the control group showed no significant change. MVPA levels increased significantly at the end of the intervention (p<.001) in the intervention group only. Height and weight of the control group also increased significantly (p<.05) but BMI did not. The percentage of the day spent sitting/lying, standing and stepping was also analysed. This can be seen in Figure 6.2 along with the hours spent. There was no significant time or group interaction from pre to post in relation to time spent sitting/lying, standing and stepping.
Table 6.4 Pre to post test results of intervention and control groups

<table>
<thead>
<tr>
<th></th>
<th>Intervention (n=16)</th>
<th></th>
<th>Control (n=17)</th>
<th></th>
<th>Time*group interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>p=</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162 (± 8)</td>
<td>162 (± 8)</td>
<td>.241</td>
<td>161 (± 5.3)</td>
<td>162 (± 5.4)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.3 (± 9.4)</td>
<td>59.5 (± 8.2)</td>
<td>.076</td>
<td>61.5 (± 7.1)</td>
<td>63.2 (± 8.6)</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>21.3 (± 6.9)</td>
<td>22.1 (± 6)</td>
<td>.090</td>
<td>23.8 (± 5.6)</td>
<td>25.2 (± 7)</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>24 (± 3.3)</td>
<td>23.3 (± 4.5)</td>
<td>.659</td>
<td>24.4 (± 2.7)</td>
<td>24.5 (± 2.8)</td>
</tr>
<tr>
<td>20 Meter Shuttle Run</td>
<td>36 (± 9)</td>
<td>52 (± 13)</td>
<td>&lt;.001**</td>
<td>42 (± 8)</td>
<td>43 (± 12)</td>
</tr>
<tr>
<td>Test (Laps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated VO$_{2\text{max}}$ (ml.kg.min$^{-1}$)</td>
<td>27.6 (± 3.6)</td>
<td>33.6 (± 4.7)</td>
<td>&lt;.001**</td>
<td>29.7(± 3.2)</td>
<td>30.1 (± 4.4)</td>
</tr>
<tr>
<td>MVPA per day (mins)</td>
<td>11 (± 7)</td>
<td>20 (± 15)</td>
<td>.013*</td>
<td>17 (± 17)</td>
<td>20 (± 17)</td>
</tr>
</tbody>
</table>

*p<.05, **p<.001
† Significant time*group interaction,
†† Sig time effect - for the group as a whole there were sig changes from pre to post test.
6.6 Discussion

6.6.1 Intervention One

This after school intervention was intended as a pilot project and many lessons were learned. Two accelerometers were purchased in the closing weeks of the intervention and were piloted with 4 participants at post test level. This pilot study allowed the investigator to become familiar with the nature of interventions and to become au-fait with the accelerometers. Any issues with usage, initialisation and downloading were identified and rectified before the start of the intervention two.

There were some methodological issues with this pilot intervention which meant that running statistics on the data would not be suitable. Attendance at the classes declined throughout the weeks often due to participant time constraints but mainly due to lack of support from the co-operating teacher and the school as a whole. It was felt that the duration of each aerobic dance classes was not sufficient or the intensity not high enough to elicit a change. The screening data (Tables 6.1 and 6.2 and Figure 6.2) do give an
insight into the low physical activity levels and adverse body composition of this group. It would seem that a school supported intervention that is independent of PE and the traditional games like rugby and soccer is warranted.

6.6.2 Intervention Two

The school timetabled intervention was employed as the attrition rate for the after school intervention was high. It was not compulsory for participants in this project to become part of the intervention or control groups but once they agreed to participate in the intervention group they had to attend these classes like they would every other school class. There was an opt-out option where they would join another subject but no participant took this option and it was hypothesised that this was because the alternate subject was considered ‘boring’. Participation rates varied depending on what activity was being done with the dance based and more novel activities getting full participation.

The intervention did not alter measures of body composition and the whole groups BMI increased significantly from pre to post. This is to be expected as adolescence represents a critical period for the increase in weight and development of obesity (Dietz, 2004). The intervention did not have a dietary element and physical activity interventions without a dietary intervention have had mixed results. MVPA increased significantly in the intervention group only. While this increase may seem small an intervention can help to prevent the decline in physical activity as girls travel through adolescence (Stone et al., 1998). This preventative approach may be more feasible and valuable.

The detrimental effect of sedentary activities on health outcomes has been discussed in section 2.4.1 and 8.1. A rudimentary measure of sedentary was derived from ActivPAL data. Time spent sitting/lying decreased marginally in both group and time spent upright increased. It seems that time spent in this sitting was replaced with time standing and time stepping. While these were not significant changes the direction of the non-significant change is encouraging. These changes cannot be attributed to the intervention, however, and possibly was a seasonal influence. When working with sedentary populations it may be more beneficial to promote light activities to replace sedentary activities.
6.6.3 Adherence to Physical Activity Recommendations

All pre test free living physical activity data from both groups were pooled and analysed as one group. 17 participants had 4 or more days of full data. No participant met the recommended physical activity levels for children (60 minutes) or adults (30 minutes). MVPA was assessed using 10 minute bouts rather than total MVPA which could lead to a more conservative result but this method has been used for large scale data interpretation (Troiano et al., 2008). While this sample was not a representative sample of the adolescent female population, these results are worrying and differ dramatically to an analysis of HBSC data which highlights Irish children as being the ‘most active’ out of 32 countries (Borraccino et al., 2009). This study also includes a measure of inactivity (sit/lie data) which is important when working with sedentary participants and drawing conclusions about activity versus inactivity levels (Pate et al., 2008). These results would be in agreement with a recent large scale US study that found that by ages 16 years and over, “mean levels of moderate activity are low and vigorous activity is almost nonexistent” (Troiano et al., 2008). Physical activity levels were determined to be below the acceptable level in both groups at pre test level but this was to be expected as this cohort was chosen due to their sedentary patterns).

6.6.4 Reflections on the Intervention

The key lessons learned from these two interventions were that it must be timetabled somehow and school support is needed. The physical activity intervention increased participants physical activity levels but not enough to reach adult (Haskell et al., 2007) or Irish child (Department of Health and Children, 2009) recommendations. But any increase is noteworthy since the group started from a sedentary base and this is combined with an increase in cardiovascular fitness. Further intervention should be employed in a similar manner but using more sensitive lab based testing and using a best practical accelerometry protocol to fully understand the many facets of physical activity (frequency, intensity, time and type).
6.7 Conclusions

This chapter reports on two intervention studies with Irish adolescents in a school setting. The experiences and results will aid in the planning of further interventions. There were a few key methodological issues that will be addressed in Intervention Three. Physical activity interventions are in their infancy in Ireland therefore it is hard to compare results. This type of intervention may be successful in an adolescent female population and its effectiveness may only become clear in years to come.
Chapter 7

School Based Physical Activity and Lifestyle Education Intervention
7.1 Introduction

Ireland has undergone a rapid economic growth in the last 20 years and has been transformed into a modern urbanized nation (Powell, 2003). As a result, the country has been burdened with some of the negative behavioural patterns that accompany such wealth and development (Perry et al., 2008). Sedentary pastimes, increased car transport and reliance on convenience foods are some such changes, many of which have already occurred in the United States (Gaziano, 2010). It has been reported that levels of overweight and obesity in the Irish population are rising not only to a level comparable to the United States but also at a faster rate (Department of Health & Children, 2005). Irish adolescents have one of the highest rates of obesity in Europe (Lissau et al., 2004) and are not meeting physical activity guidelines (Kelleher et al., 2003) with females often being highlighted as most ‘at risk’. As such, the Irish Obesity Taskforce Report (2005:89) recommended the development of interventions and “opportunities for physical activity…that concentrate on increasing physical activity among teenage girls”. Such interventions are not common in the Republic of Ireland, with only one other comparable study being identified in Northern Ireland which would have a different school system to the Republic (Murphy et al., 2006b). Only one study has utilised accelerometry in youth in Ireland (Alliance, 2009) but the results have not been reported.

Behavioural and social approaches to increase physical activity, reduce sedentary time, improve physical fitness and other health parameters of young people have been comprehensively reviewed (De Meester et al., 2009; Kahn et al., 2002; Salmon et al., 2007; Stone et al., 1998; Timperio et al., 2004; Watts et al., 2005). The effectiveness of school based physical activity interventions confirm varying success rates (Cameron et al., 2003; Kahn et al., 2002; Lissau, 2007; Stone et al., 1998; Watts et al., 2005; Yetter, 2009). Large scale multi-site interventions have had modest results (Webber et al., 2008) and small scale targeted studies have had mixed results (Watts et al., 2004a). Regardless of past achievements, no clear consensus has been drawn on the most appropriate or effective intervention strategy to follow. Reviews have also highlighted some methodological flaws in interventional studies including the absence of a matched control group, not using random assignment and the non-reporting of compliance and attrition rates (Salmon et al., 2007; Watts et al., 2005).
Many advances in physical activity assessment techniques have occurred in the last decade but the most significant has been the development and refinement of accelerometry-based activity monitors (Trost, 2007; Welk, 2002). Accelerometry is being utilised in many studies to measure physical activity levels where threshold for moderate and vigorous physical activity are applied to the data to classify minutes spent in same. This is done using a variety of methods: certain studies use previously published thresholds (Sirard et al., 2008) while other studies create their own for the specific population and measurement device (Treuth et al., 2004a; Webber et al., 2008). For the latter, individualised calibration is a further step that is often recommended (Brage et al., 2007; Levine et al., 2001; Ward et al., 2005; Welk, 2005), has been piloted (Barnett & Cerin, 2006) and used (Ekelund et al., 2003). Differences in body mass and movement economy can affect the accuracy of these group equations. Variability in energy expenditure has been shown in adolescent girls performing the same activities with the largest variation at lower intensity activities (Pfeiffer et al., 2006). Individual calibration aims to overcome that which in turn improves the accuracy of the data.

7.1.1 Aims and Hypotheses

The aims of this study were to engage a group of ‘at risk’ adolescent females in a physical activity and lifestyle education intervention which would increase participants moderate to vigorous physical activity (MVPA) during and also outside the intervention. Objectively measured physical activity levels would also be compared to subjective results from Ireland. The hypotheses of this study are (stated as the null hypothesis):

Ho1= A physical activity intervention will not increase participants levels of MVPA
Ho2= A physical activity intervention will not positively change participants health parameters.

7.2 Methodology

Following the experiences of Interventions one (section 6.4) and Intervention two (section 6.5) a final intervention was planned for the school year beginning in September
2008. It was run in a Second Level/Secondary school in the local city where students ages from 12-18. The school was in the top 5 schools in the city when attendance at University was considered. Again it was for Transition Year (TY) students, was timetabled. Participation in the study was not compulsory but once the students had been allocated to the intervention group attendance was compulsory in the same way they attended every other lesson. Participants were free to withdraw from the intervention and be put into the alternative class which the control group were in (film studies).

The study began in Sept 2008 and was co-ordinated with the PE teacher of the school. The PE teacher organised for the participants to be excused from school for pre testing. This teacher went on maternity leave after one month and was replaced by a substitute PE teacher. This PE teacher opened the sports hall, took attendance, was the disciplinarian and arranged for participants to be excused from the school for gym visits and post testing. She was not the point of contact between the participants and the investigator as the investigator had each participant’s mobile phone number and visa versa. She was the, however, the point of contact between the investigator and the school. I attended each activity class regardless of whether I was teaching it or not. I organised and co-ordinated the testing sessions and organised all external instructors and trips to the gym. I was assisted by two Ph.D. students during the pre and post tests. A collaborating Ph.D. student attended and assisted with the classes for the last 7 weeks. A breakdown of the intervention class content is in appendix 11.7.

7.2.1 Ethics Committee Approval

Approval was granted by the University of Limerick Research Ethics Committee (ULREC 43/08). Participants eligible for the study were given a participant information sheet, a parent/carer information sheet, a participant consent form and a parent/carer consent from. Each was appropriate to the intervention and control group. Participants who did not receive parental consent at this stage were not permitted to participate in the study or any of the classes.
7.2.2 Participants

Participating students were identified prior to the end of the preceding school term. Like Intervention two, an information evening on all subjects available in TY was held in the school and students were approached informally by the PE teacher and the TY co-ordinator. Students from Intervention two spoke to the new students to attest to their enjoyment of the intervention dubbed ‘UL Fitness’. Both teachers were briefed that they should only approach students who were not on any sports teams (in or out of school), did not partake in extra-curricular sports or activities and possibly did not take an active part in PE lessons in the previous 3 months. All these names were recorded (n=36) and were randomly assigned to an intervention (n=19) and a control (n=17) group.

7.2.3 Outcome Measures

Pre and post tests consisted of height and weight and resultant body mass index, 4 site skinfold measured percent body fat, waist circumference, blood pressure and a treadmill based CV fitness test to estimate VO$_2$max. These methods are described fully in sections 3.2 and 3.4.2. Physical Activity levels were recorded objectively for 7 days using recording accelerometry. The ActivPAL Physical Activity Logger (PAL Technologies Ltd, Glasgow, Scotland) was used at pre to post test. The technicalities have been described in section 3.6.3.1.

7.2.4 Accelerometry Protocol

This protocol is described in depth in sections 3.7. Briefly, participants were given the ActivPAL for 7 full days over 2 weeks before the intervention and over two weeks once the intervention ended. On distribution of the devices they were given oral and written instructions on how to wear them, when to take them off and some security issues. They were instructed to wear the ActivPAL 24 hours a day except when bathing or partaking in water based activities. The phone number of the investigator was given and participants were advised to make contact if the device should become lost or damaged.
7.2.5 Calibration of Accelerometer Output

The protocol is described in section 5.2.2. Briefly, all participants walked on a treadmill at 5 speeds between 3.2 to 7km.h\(^{-1}\) at 0\% gradient for 7 minutes at each speed. Each participant wore an ActivPAL on their right thigh and expired gas analysis was collected and averaged for the last 2 minutes at each speed. Mixed modelling was used to create a regression equation which related METs to ActivPAL counts, described in section 5.2.5. Valid data were collected for 24 participants who completed the protocol. ActivPAL counts thresholds have been created to estimate each intensity from a treadmill based study. Using Equation 5.2 an MVPA threshold for this adolescent female population was set at ≥3194 counts per 15 second epoch.

7.2.6 Intervention Design

The intervention group undertook a 36 week physical activity and lifestyle education intervention in addition to their normal school Physical Education (PE) classes. It was important that this intervention was not a substitute for normal PE classes. The control group participated in a non-exercise class during these times (example included knitting and film studies). Classes lasted for 40 minutes 3 times a week. The intervention was guided by Social Cognitive Theory with an emphasis on behavioural change (Bandura, 1986). The breakdown of the intervention is in appendix 11.7.

The physical activity component consisted of activities chosen by the participants, included aerobics, modern dance, salsa dancing and circuit training. A portion of the classes were taken by a variety of community based instructors. These instructors were organised to expose the participants to activities that they normally wouldn’t get a chance to experience. The classes were Pilates, yoga, kick boxing, hip hop, gymnastics, body conditioning, jazz dance and aqua aerobics. The lifestyle education component consisted of standard psychological tools such as short and long term goal setting, how to incorporate activity into a daily routine and the identification of barriers to physical activity and ways to overcome them. It included ways to increase self-efficacy. Participants were taught goal-setting techniques and self-management strategies, they identified and overcame barriers and discussed their past, present and future physical
activity. Other interventional studies have utilised SCT successfully (Lubans & Morgan, 2008; Neumark-Sztainer et al., 2003). Participants were also given pedometers and were educated about the adult 10,000 steps goal and how to self monitor using the pedometers. Trips to a local gym were also included so that participants could be inducted and fully introduced to a gym setting and the machines. Participants were also given discounts to attend the gym and were offered special offers for student memberships. The instructor who organised and co-ordinated the intervention and the individual classes was fully independent of the school—that is they were not a school teacher or a disciplinarian. Mobile phone text messages were sent to the participants as a reminder the night before each class.

7.2.7 Data Reduction

All accelerometry data were analysed on four levels (1) mean steps per day (2) MVPA in 10 minute bouts (3) all discontinuous stepping (4) time spent sitting/lying and standing. This was to optimise the comparisons that can be made with other studies. Mean steps were calculated directly from the output. All physical activity epochs over the moderate threshold were summed to give total discontinuous MVPA which is useful for energy expenditure. A custom made program called Castnet ANL IV was used to reduce the data and details of this programme and its development are in section 3.8.1 Bouts of MVPA 10 minutes or longer were identified and recorded by the programme and summed to give total and MVPA. Each 10 minute bout was allowed 2 minutes to go under the threshold. This was to allow for the natural breaks that can occur during physical activity like stopping at traffic lights during water or stopping to take a drink during a game of basketball. Other large scale studies have reported physical activity using this modified bout (Troiano et al., 2008) and Mâsse et al. (2005) found that minutes in MVPA was significantly decreased when an interruption in each 10 minute bout was not allowed.
7.2.8 Statistical Analysis

Data were tested for normality and any data that was not normally distributed underwent log transformation. A repeated measures ANOVA was used to test the data from pre to post and establish any time*group effects. Where significance was identified t-tests were used to measure pre to post test differences. All statistical analysis was done using SPSS version 16.0.

7.3 Results

Results from the intervention are seen in Table 7.3. There was significant time effects (p<.05) for CV fitness and MVPA with increases seen in both groups.

7.3.1 Participant Details and Compliance

Thirty six participants were originally targeted for the project. One who was in the control group did not complete the post tests and one from the intervention group was excluded for disciplinary reasons unconnected to the project. Participant details are in table 1. Compliance with the intervention ranged from to 78% to 94% with the majority of participants (n=15) attending regularly. Compliance with the accelerometry protocol is presented in Table 7.2. Valid data represented the number of participants with at least 4 days of physical activity data which included at least one weekend day.

Table 7.1 Participant characteristics at pre test level (n=36)

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (±DS)</td>
<td>15yr 6mo±4mo</td>
<td>164±7cm</td>
<td>58.8±10.9kg</td>
<td>21.7±2.7</td>
</tr>
</tbody>
</table>
Table 7.2 Compliance with wearing the accelerometer for the full sample

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intervention</th>
<th></th>
<th>Control</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>&lt;3 Days</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3 Days</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4 Days</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5 Days</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6 Days</td>
<td>5</td>
<td>8</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>At least 1 weekend day</td>
<td>16</td>
<td>14</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total Valid Sample</strong></td>
<td><strong>14</strong></td>
<td><strong>14</strong></td>
<td><strong>10</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

7.3.2 Physical Activity Levels Using Different Calibration Methods

Individual thresholding was used to measure physical activity levels using accelerometry. 24 participants had their own calibration equation and subsequent ActivPAL threshold for MVPA. The minutes spent in MVPA were compared for the 24 participants who completed the full treadmill calibration protocol. Duration of MVPA using individual and group equations was 26.2 (±40.0) minutes and 26.9 (±40.5) minutes respectively. There was no significant difference between the two methods (p=.538, paired t-test), and compliance with the 30 minute physical activity guideline was unaffected. Because there was no significant advantage to using the individual calibration, the group calibration threshold for MVPA was used in all subsequent calculations for both groups (n=34).
Table 7.3 Results from the intervention three including time*group interactions (±SD)

<table>
<thead>
<tr>
<th></th>
<th>Intervention (n=18)</th>
<th>Control (n=16)</th>
<th>Time*Group Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>P Value</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.9 (7.9)</td>
<td>165.1 (8.0)</td>
<td>.776</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>59.9 (12.8)</td>
<td>60.7 (13.4)</td>
<td>.277</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>21.9 (2.9)</td>
<td>22.1 (3.0)</td>
<td>.385</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>26.1 (3.4)</td>
<td>26.3 (2.6)</td>
<td>.721</td>
</tr>
<tr>
<td>Systolic (mmHg)</td>
<td>111 (12)</td>
<td>118 (19)</td>
<td>.152</td>
</tr>
<tr>
<td>Diastolic (mmHg)</td>
<td>63 (6)</td>
<td>67 (7)</td>
<td>.031*</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>71.2 (6.5)</td>
<td>70.5 (5.4)</td>
<td>.298</td>
</tr>
<tr>
<td>Sum Skinfolds (mm)</td>
<td>48.2 (11.8)</td>
<td>49.4 (11.0)</td>
<td>.406</td>
</tr>
<tr>
<td>VO(_2)max (ml.kg.min(^{-1}))</td>
<td>34.9 (4.1)</td>
<td>37.2 (5.8)</td>
<td>.213</td>
</tr>
<tr>
<td>MVPA (mins)#</td>
<td>23 (29)</td>
<td>32 (26)</td>
<td>.050</td>
</tr>
<tr>
<td>Steps per day #</td>
<td>9836 (2591)</td>
<td>10810 (3244)</td>
<td>.117</td>
</tr>
</tbody>
</table>

* Significant at p<.05 level    ** significant at p<.01 level
† Sig group effect   †† Significant time effect - for the group as a whole there were sig changes from pre to post.
# Due to invalid data, physical activity data are based on n=14 intervention group participants and n=10 control group participants.
Figure 7.1 Percentage of Waking Hours spent sitting/lying, standing and stepping from pre to post test. No significant differences were found (repeated measures ANOVA).

Figure 7.2 Number of participants in the intervention group meeting adult (green) and child (yellow) MVPA recommendations. This was for the full intervention group at pre test regardless of the number of valid days accelerometry they provided.
7.4 Discussion

This study was a targeted school based intervention which used randomisation, a control group and an objective measure of physical activity following a best practice protocol. School based physical activity interventions have been used to varying success in adolescent populations but not in an Irish context.

7.4.1 Intervention Results and Analysis

In Ireland, physical activity interventions are in their infancy. A search of Sports Discus, Web of Science and Pubmed using the key words physical activity, intervention and adolescents revealed little data from Ireland. In a study from Northern Ireland designed to increase bone health in adolescent females, Murphy et al. (2006b) reported an increase in self reported physical activity levels after a 6 month teacher led intervention. The cohort were similar in age, BMI and estimated CV fitness as the cohort in the present study; intervention group BMI did not change but the control groups did increase. Bone health was not measured in the present study but it is hypothesised that this would have increased due to the impact in the aerobics classes. Other studies have found no significant change in BMI (McMurray et al., 2002) body composition (Ambler et al., 1998; Schofield, et al., 2005) or physical activity (Neumark-Sztainer, et al., 2003; Schofield, et al., 2005; Webber, et al., 2008) following physical activity interventions.

7.4.1.1 Body Composition

The results from this intervention are mixed. Weight, BMI and skinfold estimated percentage body fat increased slightly in both groups but not significantly. Increases in body weight are a normal accompaniment of the growth and maturation of adolescence (Dietz, 2004) so a physical activity intervention that can prevent or slow down the normal increase in body weight cannot be underestimated. It may not be surprising that the intervention did not have an effect on body composition levels as the mean BMI in this cohort was within the normal range (< 85th percentile) as per UK growth reference charts (Cole et al., 1995). The inclusion of normal weight girls was a positive factor as
inclusion of just overweight girls could have led to negative stigmatisation (Ryan et al., 1998). Other studies have employed this technique by just focusing on those who are sedentary (Schneider et al., 2008) or including those who may only be at risk of becoming overweight or obese (Neumark-Sztainer et al., 2003). Changing nutritional behaviours was not focused on but often questions about dieting and healthy eating came up in the educational sessions and these questions were answered.

7.4.1.2 Physical Activity

Physical activity and steps per day increased in both groups but not significantly. These trends may suggest that a targeted intervention could prevent the decline in physical activity associated with adolescence. This type of preventative approach may be more valuable (Stone et al., 1998). MVPA data in the intervention group was higher to begin with and while they did not meet childhood recommendations (60 minutes) the intervention group moved towards reaching adult recommendations of 30 minutes MVPA by the post test. The average MVPA masks a large difference within the intervention group. Figure 7.2 shows how many participants met the 60 minute (child) and 30 minute (adult) MVPA recommendations on 0 to 6 days. Data is displayed using both recommendations ages 16-18 are a grey area with regard to physical activity recommendations. This age group should be attempting to accumulate 60 minutes of MVPA on most days of the week but in reality they are moving towards an a more adult like physical activity pattern. Although steps per day do not give an indicator of intensity, the accumulation of 10,000 steps per day has value in indicating population activity levels physical activity of adults (Tudor-Locke & Bassett, 2004). Higher step accumulations also have value for children (Tudor-Locke et al., 2008; 2004). The results may not be too surprising. Dobbins et al. (2009), in a review of the literature found that evidence from intervention studies do not strongly support increasing leisure time physical activity rates among adolescents.)

Promotional health messages should not only focus on promoting physical activity but also promote a decrease in sedentary activities (Healy et al., 2008a; Hu et al., 2003). Even though sedentary levels were an outcome measure in this study, changing sedentary patterns were not directly emphasised-only physical activity was aimed to be increased. It was hypothesised that if MVPA increased then sedentary time would decrease but in
reality this may not have happened. It has been suggested that young people compensate for an increase in physical activity by decreasing physical activity at a later time (Wilkin et al., 2006) but a recent study using a similar age group did not support this theory (Baggett et al., 2010). Young et al (2006) found a significant reduction in the percentage of the intervention group (22.3% down to 17%) who reported engaging in sedentary behaviours for more than 3 hours a week. Even though there was no significant changes in sedentary levels of this cohort light activity levels and the pattern in which sedentary time is accumulated should be also looked at (Healy et al., 2008a).

7.4.1.3 CV Fitness

There is good evidence that interventions can increase CV fitness in girls but the long term effects are less well researched (Dobbins et al., 2009). Other school based interventions have not elicited a significant change in outcome measures but report increased enjoyment and positive psychological changes (Jago et al., 2006; Neumark-Sztainer et al., 2003). The TAAG study found no significant change in MVPA after 2 years and a 1.6 minute difference between intervention and control group after 3 years (Webber, et al., 2008) and a pedometer study found a change of 1 minute in MPA after 12 weeks (Schofield et al., 2005). The long term effects of these interventions are less well researched and it is the effects the intervention and exposure to different activities could have 5 or 10 years later which is of interest. Retention testing and follow up is necessary. Other studies have shown low retention once the intervention has been withdrawn (Taymoori et al., 2008) and this is an important element of the intervention that should be followed up.

7.4.2 Group Analysis

The aim of this intervention was to target an ‘at risk’ group, a group of adolescents who had a more unfavourable body composition and physical activity profile than their peers. This does not seem to be the case. When group descriptives are compared to a random cross-sectional sample of adolescent females described in Chapter 8, there were no significant differences (p<.01). The group from this study, who were supposed to be ‘at risk’, did not differ to the average population described in Table 8.3. The group from this
study were no heavier, unfit or less active than the random sample even though they were pre-selected or targeted to be such. The question would be raised whether the group described here are not at risk at all as they are like the random sample. Or is it that both the sample here and the random sample are at risk of the problems associated with overweight and inactivity as each other?

Group descriptives from this study are similar to findings from Northern Ireland (Boreham et al., 2001) and Ireland (Woods et al., 2004). BMI results are slightly higher in the present study compared to Irish data previously reported by Lissau et al. (2004) but the latter data used self reported height and weight which can often be underestimated (Bray, 2009).

7.4.2.1 Physical Activity

Physical activity data were analysed further for the whole group. When participants who had 4 or more days of data (regardless of whether it included a weekend day) were included in the analysis (n=24 pre test; n=25 post test) it was found that only 3 participants achieved 150 minutes per week. This changed to 8 at post test (6 intervention and 2 control). This is graphically displayed in Figure 7.3. 150 minutes equates to the adult recommendation of 30 minutes of MVPA on 5 or more days per week (Haskell et al., 2007) and this is the more generous since those under 18 should aim to reach 60 minutes. These results would be in agreement with a recent large scale study of physical activity in the United Stated where it was found that by ages 16 years and over, “mean levels of moderate activity are low and vigorous activity is almost nonexistent” (Troiano et al., 2008). Physical activity levels were determined to be below the acceptable level in both groups at pre test (which is as expected since they were chosen due to their sedentary patterns). While physical activity levels may also not seem too low, in the intervention group especially, the mean MVPA at pre and post hides a huge variance. The range of MVPA was 0 minutes per week to 4 hours per week and one participant even recording 11 hours MVPA per week.
Figure 7.3 Minutes spent in moderate to vigorous activity per week and number of participants achieving each target

Figure 7.1 shows how the majority of participants are below the recommended physical activity levels. While this sample was not a representative sample of the adolescent female population, these results are worrying. They also differ dramatically to an analysis of the Health Behaviour of School-aged Children (HBSC) data which highlighted Irish children as being the ‘most active’ out of 32 countries (Borraccino et al., 2009). This study also includes a measure of inactivity (sit/lie data) which is important when working with sedentary participants and drawing conclusions about activity versus inactivity levels (Pate et al., 2008).

7.4.2.2 Body Composition

In a representative Northern Irish sample, with comparable anthropometric data as this group, the sum of 4 skinfolds tracked strongly from adolescent to adulthood (Boreham et al., 2004). While it may be said that this cohort did not have an adverse body composition, it was their physical activity levels that made them an ‘at risk’ group to be included for study randomisation in the first place.
7.4.3 Individual versus Group Calibration

Individual calibration of physical activity monitors are more regularly used with heart rate monitoring (Brage et al., 2007; Ekelund et al., 2003) as it can be affected by variables other than exercise such as caffeine and emotions. Body mass, movement economy and biomechanical factors can all affect the relationship between oxygen uptake and accelerometry outputs making individual calibration seem necessary (Welk, 2005). Stone et al. (2009) found that using individual accelerometer thresholds did not change the physical activity and health relationship. We did not find any difference for mean MVPA or compliance with physical activity recommendations with or without individual calibration. This is important if large scale surveillance is the aim and individual calibration is not feasible.

7.4.4 Compliance with the Accelerometry Protocol

Compliance with 4 days or more of accelerometry data was low so it was decided to include participants with 3 days or more of valid data. This may have skewed the MVPA data for those participants as perhaps they removed the accelerometer on their less active days. A common refrain when participants were asked about their lack of full valid data was that ‘they forgot’. Text message reminders were built into the intervention study to remind participants to bring their PE kit for the intervention classes, a text message to remind them to wear the accelerometer would also be necessary.

7.4.5 Reflections on the Intervention

A post hoc power calculation was undertaken to investigate to what extent the sample size might have been a limitation (Rosner, 2006:253). Using the sample sizes above, this study has a 25% chance of detecting an 80% change in MVPA from pre to post level. To detect a large change (80%) 142 participants would have been needed. This suggests that larger studies would be more desirable and this is taken on board for future studies.
This intervention was fully independent of the normal school teachers and no part of the intervention was implemented by them. Other interventions often utilise school staff to implement the activity classes (Neumark-Sztainer et al., 2003). The intervention focused on promoting lifelong physical activities and individual activities. Participation in individual sports and activities has been shown to carry from youth into adulthood better than team activities (Lunn, 2006). Free use of the largest sports complex in the city which is also attached to the University (the University Arena) was arranged so participants could use the gym or do the group fitness classes during the holidays. Four participants availed of this but these were girls who were motivated to being physical active anyway.

Attendance at the school-based intervention classes was not an issue as participants had to attend the class as they would every other class. Participation in the physical activity classes was usually high especially when doing a novel activity. They would always ‘give it a go’ and this was an important element to the intervention. It was important not to repeat activities too often or they would get bored.

Reactivity has been described earlier in section 2.8.4.5 as participants altering their normal physical activity levels when they know they are being monitored. Although reactivity has been shown not to be an issue with pedometers (Behrens & Dinger, 2007; Ozdoba et al., 2004) this cannot be discounted where the novelty of this new device caused extra physical activity. The effect of this reactivity was limited by discounting the first day of accelerometry monitoring and beginning the analysis at 7A.M. on the next morning. The intervention group had a higher level of physical activity at baseline. This cannot be explained other than they knew they has signed up to an intervention which aimed to increase physical activity levels. Perhaps thought they would be ‘doing the instructor a favour’ by registering more physical activity than normal at pre test.

The aims of the intervention were to engage a group of ‘at risk’ females in a physical activity intervention that was organised to be independent of PE and included activities chosen by the girls. These aims were met. This intervention (and also intervention one and two) can be seen as exploratory as per the UK Medical Research Council guidelines for developing and evaluating complex interventions (MRC, 2008). The interventions aimed to address some key uncertainties in how a physical activity intervention should be run in Ireland. Design and results from international studies have been reported but this
has not been tested in a Republic of Ireland context. The results from this intervention differed from the results of intervention two. One would expect that intervention three would be more successful as it built upon the successes and failures of the previous two interventions. The reasons for this can only be speculated upon. One possible reason for the differences in CV fitness results could be that the intervention group from intervention two had lower CV fitness at pre test (27.6 ml.kg.min-1) than those in intervention three (34.9 ml.kg.min-1). This means there was more room for improvement. The same could be said for MVPA levels with the intervention group from intervention three starting with higher MVPA levels. Another possible reason is that much of the higher intensity classes happened near the end of intervention two whereas fun and novel activities abounded at the end of intervention three. Any improvements in CV fitness may have faded by the end of the intervention.

7.5 Conclusions

The physical activity levels are in agreement with international studies yet contradict certain Irish data which were obtained from subjective and recall measures. Data suggests that this type of targeted school based intervention may be successful in an Irish school setting. This Irish Secondary School based intervention could be seen as a pilot work for future larger studies.
Chapter 8

Sedentary Patterns and Health Parameters in a Cross-Section of Irish Adolescent Females
8.1 Introduction

Physical inactivity (or lack of physical activity) has been shown to be an independent risk factor for a number of diseases in adults including cardiovascular disease (Blair et al., 1995; Kannel & Sorlie, 1979; Paffenbarger et al., 1986), hypertension (Chobanian et al., 2003), high blood pressure (Murphy et al., 2006a), obesity and its co-morbidities and Type II diabetes (Hu et al., 2001; Rana et al., 2007) and other cancers (Bouchard et al., 1994). As such physical inactivity has been regarded as the biggest threat to public health in the 21st century (Blair, 2009). However, someone who is deemed inactive or not meeting physical activity recommendations may not in fact be sedentary (Pate et al., 2008). Sedentary behaviour should be treated and investigated as a separate construct (Hamilton et al., 2007).

The relationships between sedentary levels and health parameters highlight a need for sedentary behaviours to be separated from inactivity in terms of health risk. Self reported sedentary levels are positively associated with the incidence of coronary heart disease (Taylor et al., 1962) and the metabolic syndrome and its risk factors (Ford et al., 2005; Gustat et al., 2002; Hu et al., 2003) in adults. Self reported TV viewing has been related to obesity (Dietz & Gortmaker, 1985; Gortmaker et al., 1996), relatively poorer physical fitness (Tucker, 1986) and body composition (Marshall et al., 2002) in children. Conversely, self reported TV viewing has been weakly or not associated with body composition (DuRant et al., 1994; Tucker, 1986; Vandewater et al., 2004), physical activity (DuRant et al., 1994; Marshall et al., 2002; Robinson et al., 1993) and health related fitness (Katzmarzyk et al., 1998). Longitudinal studies have linked time spent in sedentary activities, such as self reported TV viewing in childhood, to adverse health outcomes in adulthood (Hancox et al., 2004). Before public health messages can incorporate the promotion of a decrease in sedentary activities a strong link between these sedentary activities and health outcomes need to be confirmed. Sedentary activities must be objectively measured and conclusions about sedentary levels should only be drawn if sedentary behaviour has actually been measured (Pate et al., 2008).

The complex interlinks between sedentary levels, physical activity levels and health outcomes are less well researched. Some recent studies have indicated that sedentary
levels are associated to health outcomes independent of physical activity levels. Essentially this meant that the individual met physical activity recommendations yet was still at a health risk due to their sedentary levels (Healy et al., 2008c). Sedentary levels had negative effects on glucose tolerance, waist circumference and other metabolic risk measures independent of physical activity levels (Dunstan et al., 2007; Dunstan et al., 2004; Healy et al., 2007; Healy et al., 2008b; Healy et al., 2008c). Similar associations were seen with metabolic risk factors in children (Ekelund et al., 2006a). Heart rate measured sedentary time was associated with prospectively measured fasting insulin independent of MVPA levels in adults (Helmerhorst et al., 2009). Conversely Ekelund et al (2009b) found that whilst time spent in moderate to vigorous physical activity (MVPA) was positively related to insulin sensitivity, sedentary and light activities were not.

Given the mounting evidence and the interest in the adverse effects of sedentary behaviours, accurate and valid measures of sedentariness are necessary (Clark et al., 2009). Like with the measurement of physical activity previously, the measurement of sedentary behaviours has relied on self report. Studies have also quantified sedentary behaviour using proxy measures such as time spent watching TV or playing video games (Gustat et al., 2002; Lubans et al., 2009; Myers et al., 1996; Young et al., 2006). These do not represent the full spectrum of sedentary activities. Accelerometry has overtaken self-report as a widely used measure of free living physical activity and it is now being used to measure sedentary behaviours (Janz et al., 2005; Matthews et al., 2008; Reilly et al., 2003; Treuth et al., 2005). Various thresholds to define sedentary levels have been published for children and adolescents (Ekelund et al., 2004; Puyau et al., 2002; Reilly et al., 2003; Treuth et al., 2004a) which have been utilised in free living physical activity measurement (Ekelund et al., 2004; Sirard et al., 2008; Treuth et al., 2005). Measuring sedentary activities without the use of thresholds (Freedson et al., 2005) would seem to be the way forward. Accelerometers now incorporate inclinometers or activity classification systems allowing body position to be determined. One such accelerometer is the ActivPAL physical activity logger (PAL Technologies Ltd, Glasgow, UK) which incorporates Intelligent Activity Classification based on a microelectrical mechanical systems (MEMS) microprocessor. Recorded epochs are classified into periods of sitting/lying, standing and stepping. Time spent sedentary (defined as sitting/lying) can be estimated along with light intensities and greater (defined as standing and stepping).
8.1.1 Aims and Hypotheses

The purpose of this study was to use an objective measure of sedentary behaviour to quantify sedentary levels and patterns in a cohort of female adolescents. Older adolescents have been shown to be a particularly sedentary population (Matthews et al., 2008) and this needs to be investigated in an Irish context. Once quantified, the emerging interlinks between sedentary levels, physical activity levels and health outcomes were investigated. The hypotheses (stated as the null hypothesis) of the study were:

Ho1= Sedentary levels are not significantly related to health parameters independent of physical activity levels.
Ho2= There is no significant difference in sedentary levels and patterns and physical activity between weekdays and weekend days.

8.2 Methodology

This chapter contains data from a study on second level schools called The Limerick Physical Activity Study (also called LPAS) which has not been previously described. I planned, gained ethics approval for, co-ordinated and ran the project with one other Ph.D. student, Kieran Dowd. Testing was done by myself and Kieran Dowd with Katy Horner measuring skinfolds. A 7 day recall questionnaire was used also but these data are part of Kieran Dowd’s Ph.D. research and I present data from two questions only. Physical activity data reduction and analysis was done by both myself and Kieran Dowd. I reduced and analysed the sedentary data and subsequent analysis.

8.2.1 Recruitment

LPAS aimed to investigate the health and physical activity levels of a cross-section of Irish adolescent females from the Mid-West area. Approval was granted by the University of Limerick Research Ethics Committee (ULREC 08/67). Initially six schools were chosen at random from a Department of Education online list of Second Level Schools using a random numbers table. Schools were excluded if they had no female
students or didn’t offer a Transition Year (TY) programme. One school declined to participant and another could not due to timetable constraints. A further two schools were then chosen at random. Principals from each school were sent a letter of invitation and this was followed up with a phone call to the principal and the co-operating teacher (typically the PE teacher). A list of all students in the school between the ages of 15 and 17 were sent to the investigators. 15 students were randomly selected from each school using a random numbers table and invited to participate. Investigators visited each school to meet the teacher and the 15 students selected. Here participant and parent/carer information sheets and consent forms were distributed to each student and a brief overview of the study was given. For participant’s whose parents/guardians did not read English well, all forms were translated. The forms were translated into Russian and Slovak for 3 participants. The investigators returned one week later for the test session. Only those who had given full consent and received parental consent and were present in school for the test day could participate. A breakdown of the number of participants who were randomly chosen (n=92) but declined to be involved or were absent from school is included in Table 8.1.

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participated</td>
<td>56</td>
<td>60.9</td>
</tr>
<tr>
<td>Absent (either before or after consenting)</td>
<td>21</td>
<td>22.8</td>
</tr>
<tr>
<td>Sporting Commitment</td>
<td>2</td>
<td>2.2</td>
</tr>
<tr>
<td>Consented but did not Participate</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>No Consent</td>
<td>7</td>
<td>7.6</td>
</tr>
</tbody>
</table>

### 8.2.2 Protocol

The study methodology took place in the school setting during a double class. Participants arrived with their own completed informed consent and consent from their parents/guardians. Procedures were undertaken in the order of height, weight, blood pressure, skinfolds, waist circumference and cardiovascular (CV) fitness test. Each participant was then given an accelerometer along with a full verbal and written demonstration. This protocol to promote compliance is described in section 3.7.10.
Participants were instructed to wear the accelerometer for a full 7 days, 24 hours a day (including when sleeping) and were only to be removed for bathing, swimming or before any other water based activities. Participants affixed the ActivPAL on the midpoint of the midline of the anterior right thigh using a hydrogel pad. A tubegrip elasticated bandage was then worn over the device for further protection. Accelerometers had been initialised when connected to the laptop before the arrival of the participants.

Two days following this test an investigator visited the school and gave a questionnaire to the participants. This questionnaire was not part of the present study but it did contain two questions in the opening general information section about time spent watching TV and playing computer games (appendix 11.12).

### 8.2.3 Measurements

Participants wore light clothing for all measures. Height, weight, BMI, 4-site skinfold technique and waist circumference were measured as in section 3.2. Blood pressure was measured as per section 3.3. CV fitness was measured using the 20-MST as per section 3.4.2.

### 8.2.4 Accelerometer

The ActivPAL™ professional physical activity logger (PAL Technologies Ltd, Glasgow, Scotland) was used to assess physical activity levels and sedentary patterns. The ActivPAL details have been described in section 3.5.3.1. The device has three main outputs for use when investigating free-living activity in this context: inclination of the body—whether the participant is sitting or lying (sedentary), standing or stepping, number of steps or cadence in real time and also accelerometry ‘counts’ which, like other accelerometers, are an arbitrary number summed for every 15 second epoch.
8.2.5 Data Analysis and Reduction

To be included in the analysis participants had to provide at least 4 days of valid data including one weekend day. A valid day was considered to be 600 minutes or more of data. For the purposes of this paper, sedentary time is defined as time spent in the activities of sitting/lying, standing is not considered a sedentary activity in this analysis. Other studies have used thresholds for sedentary activities which they assumed included activities like standing (Healy et al., 2008a). In this present study a break in sedentary activity was defined as a disruption in a bout of sedentary activity of 15 seconds or more. A break in sedentary activity was defined as time spent standing and stepping.

Output from the ActivPAL includes time spent sitting/lying and standing for every 15 second epoch (Figure 3.7). Data were saved as a weekly summary file and the following were calculated as per section 3.7.13.3.

- Steps per day were totalled from the output.
- Total hours spent sitting/lying, standing and stepping were summed from the output for the full 24 hour day.
- Sit to Stand Transitions: These were totalled from the output.

The following variables were not available in the ActivPAL directly but were extracted by the investigator manually. A ‘rule’ was set to define each variable and this was followed for each individual data set. Such manual reduction could be subject to some error. This was minimised by having only one investigator reduce the data; intra-tester coefficient of variation was deemed acceptable at 4%.

- Wake Hours: This began the minute when the participant first registered a step which was not followed by 60 minutes or more of zero counts. Wake hours ended the minute 180 minutes or more of sitting/lying was registered from the hours of 7pm onwards.
- Bed Hours: Wake hours were subtracted from 24 hours. It was not appropriate to call this measure “sleep hours” as it was not known if the person was actually sleeping or just sitting or lying down. For example a person may read a book or watch TV in bed before going to sleep.
• Total Waking Sedentary Time: This was calculated by subtracting the time spent sedentary at night (Bed Hours) from total time spent sitting/lying over the full 24 hour day. This represented total time spent sedentary during waking hours.

• Non-Wear Time: As described in 3.7.8. The output from each day was scanned visually for breaks in activity that were 60 minutes or more in duration. Once these were identified, the counts data (epoch results) were analysed to see whether the break was non wear time (60 minutes of 0 counts). These were deleted and the 24 hour day adjusted accordingly.

The above variables only give a representation of the volume of sedentary activity and do not give any information about the manner in which the sedentary time is accumulated. Of interest is the number and duration of each sedentary bout. This analysis required further data reduction. Manual reduction was quite time consuming so to eliminate the potential for error a Matlab™ programme was developed. This programme and its development are described in section 3.8.2. In the programme dynamic bouts are calculated to represent a break in a sedentary bout that lasts at least 15 seconds. This is when the participant moves from sitting/lying to standing and/or stepping. This break shall be referred to as a Break in Sedentary Activity in this chapter. The following were the outputs calculated:

• Mean length of each sedentary bout
• Maximum length of the sedentary bout
• Number of sedentary bouts
• Mean length of each break in sedentary activity
• Maximum length of the break in sedentary activity
• Number of breaks in sedentary activity.

The manner in which sedentary activity is accumulated can also be investigated in terms of the number of breaks per hour spent sedentary (Healy et al., 2008a). To calculate this, total waking sedentary time was simply divided into the number of breaks in sedentary activity.

Moderate to vigorous physical activity per day was defined as the total time spent in modified 10 minute bouts (Troiano et al., 2008) per day. These bouts are described in
section 3.7.13.2 and the analysis followed the protocol in 3.8.1. The threshold for MVPA was set at 3194 ActivPAL counts per 15 seconds following the equation developed for adolescent females in Chapter 5 (Equation 5.2).

8.2.6 Statistical Analysis

Means, standard deviations (±SD) and ranges were computed using Microsoft Excel. Skewness and kurtosis were assessed and variables that were not normally distributed (BMI, MVPA and steps) were log transformed. Independent sample t-tests were used to compare weekday and weekend activities. Pearson correlations were employed to investigate the relationship between physical activity, sedentary activity and health parameters. Forced entry linear regression analysis was employed to further investigate the sedentary, physical activity and health interlink. All statistical analysis was run using SPSS Version 16.0 (SPSS Inc, Chicago, IL, USA).

8.3 Results

The measured health parameters are tabulated in Table 8.3. Data on blood pressure must be viewed with caution as the systolic blood pressure of a significant number of participants was measured as extremely high (>140mmHg). We hypothesise that some participants were not properly rested before the blood pressure measurement or the ‘excitement’ of the test day and the lack of calm and quite may have affected the measure.

8.3.1 Participants

All participants were full time Second level students and two were not Irish nationals. Out of the 56 who participated, 6 did not have a set of at least 4 days of valid recorded data and include a weekend day. The first day of the 7 day accelerometry protocol was excluded so the maximum number of days any participant could have was 6 days.
Table 8.2 Compliance with wearing the accelerometer for the full sample (n=56)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4 Days</td>
<td>5</td>
<td>8.9</td>
</tr>
<tr>
<td>4 Days</td>
<td>9</td>
<td>16.1</td>
</tr>
<tr>
<td>5 Days</td>
<td>16</td>
<td>28.6</td>
</tr>
<tr>
<td>6 Days</td>
<td>26</td>
<td>46.4</td>
</tr>
<tr>
<td>At least 1 weekend day</td>
<td>54</td>
<td>96.4</td>
</tr>
<tr>
<td>Total Valid Sample</td>
<td>50</td>
<td>89.3</td>
</tr>
</tbody>
</table>

Table 8.3 Participant characteristics (n=56)

<table>
<thead>
<tr>
<th></th>
<th>Mean ±SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>15y 11mo</td>
<td>15y 1mo-17 9mo</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.75</td>
<td>150.0-179.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.2</td>
<td>42.4-89.8</td>
</tr>
<tr>
<td>BMI (kg.m$^2$)</td>
<td>21.7</td>
<td>15.9-30</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>118</td>
<td>94-151</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>75</td>
<td>58-109</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
<td>71.3</td>
<td>59.5-97</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>27.3</td>
<td>18.1-37.0</td>
</tr>
<tr>
<td>VO$_2$ (ml.kg.min$^{-1}$)</td>
<td>31.8</td>
<td>23.5-45.3</td>
</tr>
</tbody>
</table>

Table 8.4 Classification of participant’s (n=56) body composition according to adults WHO BMI classification, International Obesity Taskforce cutpoints (Cole et al., 2000) and UK growth reference data (Cole et al., 1995).

<table>
<thead>
<tr>
<th></th>
<th>Underweight</th>
<th>Normal</th>
<th>Overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO (Adult)</td>
<td>7</td>
<td>39</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>IOTF</td>
<td>N/A</td>
<td>45</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>UK</td>
<td>N/A</td>
<td>40</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>±SD</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------</td>
<td>------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>MVPA (minutes per day)</td>
<td>25</td>
<td>16</td>
<td>0-61</td>
<td></td>
</tr>
<tr>
<td>Steps Per Day</td>
<td>8941</td>
<td>2436</td>
<td>4508-16057</td>
<td></td>
</tr>
<tr>
<td>Sitting/lying (hrs)</td>
<td>19.0</td>
<td>0.9</td>
<td>16.8-20.8</td>
<td></td>
</tr>
<tr>
<td>Standing (hrs)</td>
<td>3.3</td>
<td>0.7</td>
<td>1.8-5.3</td>
<td></td>
</tr>
<tr>
<td>Stepping (hrs)</td>
<td>1.7</td>
<td>0.4</td>
<td>0.8-2.8</td>
<td></td>
</tr>
<tr>
<td>Wake Hours (hrs)</td>
<td>14.3</td>
<td>0.8</td>
<td>12.7-16.0</td>
<td></td>
</tr>
<tr>
<td>Bed Hours (hrs)</td>
<td>9.8</td>
<td>0.8</td>
<td>8.0-11.3</td>
<td></td>
</tr>
<tr>
<td>Total Waking Sedentary Time (hrs)</td>
<td>9.2</td>
<td>1.2</td>
<td>6.8-12.5</td>
<td></td>
</tr>
<tr>
<td>% Waking Hours Spent Sedentary</td>
<td>64.2</td>
<td>6.7</td>
<td>46.8-79.6</td>
<td></td>
</tr>
<tr>
<td>% Total Day Spent Sedentary</td>
<td>79.1</td>
<td>3.9</td>
<td>70.2-86.8</td>
<td></td>
</tr>
<tr>
<td>Mean Length Sedentary Bout (min)</td>
<td>10</td>
<td>2</td>
<td>7-14</td>
<td></td>
</tr>
<tr>
<td>Max Length of Sedentary Bout (min)</td>
<td>48</td>
<td>4.2</td>
<td>39-55</td>
<td></td>
</tr>
<tr>
<td>Number of Sedentary Bouts</td>
<td>47</td>
<td>10</td>
<td>27-75</td>
<td></td>
</tr>
<tr>
<td>Mean Length Break (min)</td>
<td>7</td>
<td>2.1</td>
<td>3-15</td>
<td></td>
</tr>
<tr>
<td>Max Length of Break (min)</td>
<td>50</td>
<td>11</td>
<td>20-88</td>
<td></td>
</tr>
<tr>
<td>Number of Breaks</td>
<td>49</td>
<td>10</td>
<td>30-78</td>
<td></td>
</tr>
<tr>
<td>Breaks per Sedentary Hour</td>
<td>5</td>
<td>1</td>
<td>3-8</td>
<td></td>
</tr>
</tbody>
</table>

Participants spent significantly (p<.001) more time sedentary during weekdays than weekend days. There was no difference in steps per day or MVPA. When the pattern sedentary levels are accumulated there were some significant difference between weekdays and weekend days. These are tabulated in Table 8.6.
Table 8.6 Mean (±SD) of each sedentary and physical activity variable compared between weekday and weekend day.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Weekday</th>
<th>Weekend Day</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVPA (minutes per day)</td>
<td>24 (28)</td>
<td>25 (31)</td>
<td>.747</td>
</tr>
<tr>
<td>Steps Per Day</td>
<td>8991 (3692)</td>
<td>8985 (4833)</td>
<td>.992</td>
</tr>
<tr>
<td>Sitting/lying (hrs)</td>
<td>19.0 (1.4)</td>
<td>18.7 (2.1)</td>
<td>.110</td>
</tr>
<tr>
<td>Standing (hrs)</td>
<td>3.3 (1.1)</td>
<td>3.5 (1.5)</td>
<td>.099</td>
</tr>
<tr>
<td>Stepping (hrs)</td>
<td>1.7 (0.6)</td>
<td>1.8 (0.8)</td>
<td>.750</td>
</tr>
<tr>
<td>Wake Hours (hrs)</td>
<td>14.6 (1.9)</td>
<td>13.3 (1.9)</td>
<td>&lt;.001**</td>
</tr>
<tr>
<td>Bed Hours (hrs)</td>
<td>9.4 (1.7)</td>
<td>10.7 (1.9)</td>
<td>&lt;.001**</td>
</tr>
<tr>
<td>Total Waking Sedentary Time (hrs)</td>
<td>9.7 (2.1)</td>
<td>8.0 (2.7)</td>
<td>&lt;.001**</td>
</tr>
<tr>
<td>% Waking Hours Spent Sedentary</td>
<td>65.7 (10.6)</td>
<td>59.2 (16.4)</td>
<td>&lt;.001**</td>
</tr>
<tr>
<td>% Total Day Spent Sedentary</td>
<td>79.3 (6.0)</td>
<td>77.8 (8.6)</td>
<td>.110</td>
</tr>
<tr>
<td>Mean Length Sedentary Bout (min)</td>
<td>10.3 (2.5)</td>
<td>8.9 (2.5)</td>
<td>&lt;.001**</td>
</tr>
<tr>
<td>Max Length of Sedentary Bout (min)</td>
<td>48.1 (8.2)</td>
<td>47.0 (9.4)</td>
<td>.331</td>
</tr>
<tr>
<td>Number of Sedentary Bouts</td>
<td>49 (14)</td>
<td>47 (14)</td>
<td>.003*</td>
</tr>
<tr>
<td>Mean Length Break (min)</td>
<td>6.8 (2.7)</td>
<td>7.5 (4.6)</td>
<td>.155</td>
</tr>
<tr>
<td>Max Length of Break (min)</td>
<td>50.7 (23.3)</td>
<td>49.6 (23.4)</td>
<td>.742</td>
</tr>
<tr>
<td>Number of Breaks</td>
<td>51 (13)</td>
<td>46 (14)</td>
<td>.005*</td>
</tr>
<tr>
<td>Breaks per Sedentary Hour</td>
<td>6 (2)</td>
<td>7 (4)</td>
<td>.002*</td>
</tr>
</tbody>
</table>

* Significant difference (p<.01); ** Significant difference (p<.001).

Mean MVPA of weekday and weekend days did not meet current physical activity guidelines for children (Department of Health and Children, 2009) or adults (Haskell et al., 2007). Mean MVPA of 25 (±16) minutes per day hides the fact that over half of participants did not reach the 60 minute MVPA guideline on any day of monitoring (Figure 8.1).

The mean duration of sedentary bouts masks the fact that some sedentary bouts only last a few minutes while some last 30 minutes or more. Aggregated sedentary block data were split up into separate days for each participant and data were allocated into blocks of various durations from less than one minute to 41 minutes and greater. These data are presented in Figure 8.2 and gives a broader representation of the manner in which sedentary levels are accumulated and differences between weekday and weekend day.
Data garnered from the physical activity questionnaire in presented in Figure 8.3. The data were in response to the questions ‘How many hours a day do you usually watch TV?’ and ‘How many hours a week do you usually play computer games?’ These questionnaire data are shared with another Ph.D. student so only data on TV viewing and computer use are reported here.
8.3.2 Sedentary Parameters and Health

Bivariate correlations ($r$) between sedentary parameters, physical activity and health are included in Table 8.7. Significant correlations were found between weight, BMI and systolic blood pressure and sedentary measures. A more appropriate way to assess this relationship would be using regression with adjustment for potential confounders. Forced entry linear regression was used on the data. After adjustment for MVPA, the association between total waking sedentary time and BMI was no longer significant ($\beta = .141, p=.326$). This method was applied to all significant correlations and the same effect was evident, this data are presented in appendix 11.15 (4).
Table 8.7 Correlations between the measure of physical activity and sedentary and health outcomes (n=50)

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>BMI</th>
<th>Systolic</th>
<th>Diastolic</th>
<th>Waist</th>
<th>% Body Fat</th>
<th>CV Fitness</th>
<th>MVPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVPA</td>
<td>.152</td>
<td>.216</td>
<td>.190</td>
<td>.231</td>
<td>-.053</td>
<td>.050</td>
<td>-.340*</td>
<td>NA</td>
</tr>
<tr>
<td>Steps per Day</td>
<td>.248</td>
<td>.284*</td>
<td>.305*</td>
<td>.236</td>
<td>.094</td>
<td>-.020</td>
<td>-.077</td>
<td>NA</td>
</tr>
<tr>
<td>Sitting/lying</td>
<td>-.308*</td>
<td>-.330*</td>
<td>-.288*</td>
<td>-.155</td>
<td>-.285*</td>
<td>.004</td>
<td>-.102</td>
<td>-.211</td>
</tr>
<tr>
<td>Standing</td>
<td>.221</td>
<td>.236</td>
<td>.181</td>
<td>.070</td>
<td>.276</td>
<td>.023</td>
<td>.103</td>
<td>-.111</td>
</tr>
<tr>
<td>Stepping</td>
<td>.307*</td>
<td>.341*</td>
<td>.307*</td>
<td>.211</td>
<td>.144</td>
<td>.002</td>
<td>-.046</td>
<td>.652**</td>
</tr>
<tr>
<td>Wake Hrs</td>
<td>-.029</td>
<td>-.043</td>
<td>-.098</td>
<td>-.097</td>
<td>-.013</td>
<td>-.079</td>
<td>.007</td>
<td>-.014</td>
</tr>
<tr>
<td>Bed Hrs</td>
<td>.138</td>
<td>.156</td>
<td>.192</td>
<td>.118</td>
<td>.102</td>
<td>.105</td>
<td>-.058</td>
<td>.054</td>
</tr>
<tr>
<td>Total Waking Sed Hrs</td>
<td>-.330*</td>
<td>-.359*</td>
<td>-.357*</td>
<td>-.207</td>
<td>-.280*</td>
<td>-.076</td>
<td>.006</td>
<td>-.217</td>
</tr>
<tr>
<td>% Waking Hrs Sed</td>
<td>-.313*</td>
<td>-.339*</td>
<td>-.303*</td>
<td>-.183</td>
<td>-.273</td>
<td>-.040</td>
<td>-.020</td>
<td>-.229</td>
</tr>
<tr>
<td>% 24 Hrs Sed</td>
<td>-.310*</td>
<td>-.335*</td>
<td>-.287*</td>
<td>-.162</td>
<td>-.282*</td>
<td>-.014</td>
<td>-.051</td>
<td>-.224</td>
</tr>
<tr>
<td>Length Sed Bouts</td>
<td>-.090</td>
<td>-.060</td>
<td>-.022</td>
<td>-.133</td>
<td>-.007</td>
<td>.000</td>
<td>-.140</td>
<td>-.138</td>
</tr>
<tr>
<td>Max Length Sed</td>
<td>-.066</td>
<td>-.078</td>
<td>.026</td>
<td>-.348*</td>
<td>-.078</td>
<td>.036</td>
<td>.130</td>
<td>-.163</td>
</tr>
<tr>
<td>Number Sed Bouts</td>
<td>-.089</td>
<td>-.152</td>
<td>.014</td>
<td>.063</td>
<td>-.191</td>
<td>-.138</td>
<td>.162</td>
<td>.070</td>
</tr>
<tr>
<td>Length Breaks</td>
<td>.179</td>
<td>.277</td>
<td>.164</td>
<td>.053</td>
<td>.139</td>
<td>.072</td>
<td>-.069</td>
<td>.160</td>
</tr>
<tr>
<td>Max Length Breaks</td>
<td>.135</td>
<td>.216</td>
<td>.090</td>
<td>.196</td>
<td>.099</td>
<td>.037</td>
<td>-.008</td>
<td>.490**</td>
</tr>
<tr>
<td>Number Breaks</td>
<td>-.097</td>
<td>-.165</td>
<td>-.005</td>
<td>.066</td>
<td>-.194</td>
<td>-.146</td>
<td>.148</td>
<td>.067</td>
</tr>
<tr>
<td>Breaks per Sed Hr</td>
<td>.109</td>
<td>.077</td>
<td>.193</td>
<td>.162</td>
<td>-.012</td>
<td>-.073</td>
<td>.120</td>
<td>.191</td>
</tr>
</tbody>
</table>

* Correlation is significant at the .05 level (Pearson, 2-tailed); ** Correlation is significant at the .01 level (Pearson, 2-tailed).
8.3.3 Night Patterns

The night time sedentary patterns of the participants were analysed. The mean hours spent in bed of participants is displayed in Figure 8.4. This is not and should not be interpreted as time spent sleeping as there is no way of knowing whether the participants were actually asleep. It simply represents the time between the last movement registered by the accelerometer at night and the first movement registered in the morning. To investigate differences between week day and weekend aggregated data were split by day and each day from each participant was treated separately in this next analysis. There were 187 weekdays and 81 weekend days included to create Figure 8.5. These data may come as no surprise that adolescents spend more time in bed at weekends. Further analysis was done to identify any differences between the time participants got up and went to bed on school days and weekend days (Figure 8.6).

Figure 8.4 Mean number of hours participants spent in bed (n=50)
Figure 8.5 Comparison of hours spent in bed between weekday and weekend days.

Figure 8.6 Times when participants got up (a) and went to bed (b) compared between weekday and weekend day. Significant differences between weekday and weekend day (a) $p<.001$ and (b) $p<.01$. 
8.4 Discussion

This study measured sedentary levels in a randomly sampled group of adolescent females and investigated the patterns and accumulation of this sedentary time. The relationships of these sedentary parameters to health outcomes were also investigated. This is the first study to objectively measure sedentary levels of a cross-section of adolescents using accelerometry but without the need for thresholds or cutpoints.

8.4.1 Sedentary Levels and Patterns

The majority of the day was spent in sedentary activities, in agreement with other studies (Healy et al., 2008a; Jago et al., 2005; Matthews et al., 2008; Sirard et al., 2008; Treuth et al., 2007; Treuth et al., 2005) including Irish evidence (Woods et al., 2004). Physical activity did not differ between week and weekend days. This is in agreement with Sirard et al. (2008) while higher physical activity has been found on week days (Treuth et al., 2007) and weekends (Trost et al., 2000).

Superficially sedentary levels did differ significantly between week day and weekend days. Total waking sedentary time is significantly lower at weekends only because their waking day was shorter during the weekend. When total time spent sitting/lying and % of total 24 hour day sedentary is considered there is no difference evident between week day and weekend day levels. When the sleep-ins (later rising time, Figure 8.6a) on the weekend days are taken into account there is no difference in sedentary time. Sedentary patterns do differ between week day and weekend day and this is an important finding. The average number and duration of each sedentary bout was significantly lower at weekends. This indicates that these students were sedentary in less continuous blocks and these blocks were shorter than during the week. This is not surprising as the majority of the weekday is spent in school. Unwittingly a school setting promotes sedentary patterns during structured class time as students sit in class. These can consist of at least 35 minutes of uninterrupted sitting over many classes each day. Further analysis should focus on lunch time patterns or patterns straight after school in the same way that physical activity has been analysed.
The percentage of waking hours spent sedentary is lower than other studies (Healy et al., 2008a; Treuth et al., 2005). Other than the obvious demographic differences the reason for this could be in the differences in the classification of sedentary. Previous studies have used a practical cut-off of <100 counts per minute as a sedentary threshold for the Actigraph accelerometer (Healy et al., 2007; Sirard et al., 2008; Treuth et al., 2007; Treuth et al., 2004a). This classification may also inadvertently include some light activities. We have directly measured the position of the lower body whereby standing (often considered sedentary) is treated as a separate activity.

Studies have assumed 8 hours of sleep per day (Slootmaker et al., 2009) or have relied on self report (Steele et al., 2009). The present study was based on full 24 hours of monitoring and did not assume a standard length of a nights sleep. While one would expect a fairly stable night time pattern for school going adolescents it is futile to say that they sleep 8 hours each and every night. Average time spent in bed was 9.4 (±1.7) hours on weekdays and 10.7 (±1.9) hours on weekend days with some participants registering activity until 2am on weekend days. All participants spent an average of at least 8 hours per night in bed over the full monitoring period which is encouraging given the consequences of insufficient sleep (Carskadon, 1990). However, it would be erroneous to conclude that all participants got a minimum of 8 hours of actual sleep per night. It would be assumed that participants would watch TV, read a book or use laptops in bed before going to sleep. Irish data are sparse on adolescent TVs in bedrooms. A recent large scale Irish study found that 49% of 9 year old children had a television set in their bedroom (ESRI, 2008) and previously 33% has been reported by the Irish Southern Health Board (2004). Notwithstanding these caveats, using this full 24 hour monitoring gives a fuller picture of time spent sedentary and overall sedentary patterns. This approach would also be useful when working with participants who do shift work or with patient populations who would sleep more than the assumed 8 hours per day.

8.4.2 Sedentary Levels and Relationships with Health

This study points to some important links between sedentary parameters and health. In this cohort significant relationships were seen between sedentary levels and weight, BMI and systolic blood pressure. Studies have found relationships between sedentary levels
and measures of body composition in girls (Treuth et al., 2005). Ekelund et al. (2006), Steele et al. (Steele et al., 2009) and Marshall et al. (2004) related TV viewing to adiposity. The relationships from the present study were not independent of MVPA or steps. This means that this negative relationship between sedentary and health outcomes can be attenuated by physical activity. This is similar to a study of children where VPA was a more important predictor on adiposity (Steele et al., 2009). We found no connection between physical activity and the health parameters. When time spent sedentary was broken down into patterns, such as duration and number of sedentary bouts, these significant relationships were not seen.

The importance of breaking up bouts of sedentary activity has only recently been explored and have been provisionally linked to certain metabolic risk factors independent of physical activity and sedentary activities (Healy et al., 2008a). Light activity have been highly negatively correlated with sedentary indicating that the more participants engaged in light activities the less time they spent being sedentary (Healy et al., 2007; Healy et al., 2008b). This was in adults and this association is not seen in our data. These metabolic risks may not have manifested themselves yet and also the measures were not sensitive enough to recognise any links with disease. This would be considered a development of methods and we can now be happy to do similar research with a larger or more diverse cohort.

Levine et al. (2005) found differences in time spent sitting and time spent upright between lean and obese adult participants. As an exploratory analysis, the 6 participants with the lowest BMI were compared to the 6 participants with the highest BMI on measures of sedentary and physical activity. Significant differences were seen between groups in total time spent sitting/lying and stepping and total time spent sedentary in waking hours. The difference was not in the hypothesised direction however. Higher weight participants (n=6; BMI 27.7) spent more time stepping and less time sitting/lying and sedentary than their lower weight contemporaries (n=6; BMI 17.3). Those with a higher BMI also took significantly more steps per day (10344 versus 7250, p<.05). No significant differences were seen in these parameters between lower weight and normal weight participants and normal weight and higher weight participants similar to results found with a younger cohort (Jago et al., 2005). In section 2.2.3 it was mentioned that it is erroneous to assume that those who were overweight do no physical activity and those
who do would have more favourable body composition. This caveat is proved here as those with what would be perceived to be a more negative body composition had higher physical activity and lower time spent sedentary. This may support the hypothesis that diet has more of an impact than physical activity on weight profiles. An alternative suggestion would be that those with the highest BMI were doing something about it and engaging in physical activity to improve their body composition. Another possibility is that these participants had already been weighed and felt that they should ‘compensate’ for their higher BMI by doing a lot of physical activity during the monitoring period but this is just speculation.

![Figure 8.7 Differences in time spent sitting/lying and stepping and total waking sedentary time between lower weight and higher weight participants](image)

**Figure 8.7 Differences in time spent sitting/lying and stepping and total waking sedentary time between lower weight and higher weight participants**

### 8.4.3 Measurement of Sedentary Levels

Physical activity levels of adolescents have been well described using both subjective (Borraccino et al., 2009) and objective (Troiano et al., 2008) methods. Sedentary levels have been measured by accelerometry in adults and children (Matthews et al., 2008) and by self report diaries (Gorely et al., 2007) through the proxy measures of TV viewing (Hu et al., 2003; Robinson et al., 1993). It is more difficult to self report all time spent sedentary as it is so ubiquitous and hard to quantify.
There have been calls for more robust sedentary thresholds (Freedson et al., 2005; Matthews, 2005) and direct measure of body position (Clark et al., 2009; Matthews et al., 2008) for accurate assessment of sedentary levels. The latter groups of researchers have suggested the ActivPAL as a tool to do this. The ActivPAL's placement on the body and its use of a microelectrical mechanical systems (MEMS) microprocessor means it can distinguish the position of the body by means of the inclination of the upper thigh.

Proxy measures of sedentary levels which have been previously mentioned include TV viewing and video gaming (Ford et al., 2005; Sallis et al., 1996). It is suggested that with the advent of ‘active’ video gaming such as the Nintendo Wii platform and its various games (Wii Fit and Wii Resort), automatically classifying all computer gaming in the sedentary category is now not appropriate. These video games increase energy expenditure especially from the upper body movements (Graves et al., 2008). To classify a person as sedentary based on their time spent watching TV or video gaming would be incorrect. Total sedentary time includes a lot more than the limited behaviours of television, video games or internet access (Marshall et al., 2004; Matthews et al., 2008). To compensate for this the modified Self Administered Physical Activity Checklist (SAPAC) contains a list of eight sedentary activities (Marshall et al., 2002). While these activities aim to cover the full spectrum of sedentary behaviours they put added burden on participants as they must recall these activities. Total daily sedentary time also includes work or school related sitting time, sleep-ins, sitting for socialising, reading, homework and transport.

The limitation of accelerometry in measuring sedentary behaviours is that information on the type of sedentary activity, the location and the environmental influence is not known. This can be assessed with a concurrent diary or physical activity questionnaire that includes a sedentary element. Figure 8.3 presented selected data from a questionnaire which was filled out at the beginning of the accelerometry monitoring period. Nearly one half of participants responded that they watched TV no more than 1 hour per day. This is unlikely considering the amount of time this cohort spent sedentary during the day. It serves to highlight the difference between self report and objectively measured sedentary time and also that sedentary cannot be fully assessed using a discrete activity like TV watching.
8.4.4 Strengths of the Study

- This study used an accelerometer to quantify sedentary behaviours without the use of thresholds and this is an advantage of this study. Not only do we report on total time spent sedentary during waking hours we report on total time spent sedentary in the full 24 hour day. The accumulation of the sedentary time is also considered.
- As well as presenting data on physical activity and sedentary activity between weekday and weekend day we also highlight differences in the pattern in which the sedentary time is accumulated.
- We present an approximation of sleep patterns of this adolescent cohort which has not been measured before to our knowledge in an Irish context objectively.
- The accelerometry data collected are extremely rich and will allow for further analysis in the future. It will also allow for analysis of time spent in light intensity physical activity, a construct which is neglected in the literature but which is potentially important.

8.4.5 Limitations of the Study

- Small sample size. Caution needs to be taken when generalising these results to the whole population due to the homogeneity of our cohort. The trends are important and further research is warranted to investigate if the relationship is stronger or different.
- Other studies which have looked at the link between sedentary levels and health outcomes independent of physical activity have investigated the link with clinical measures such as insulin resistance and blood triglycerides (Dunstan et al., 2007; Ekelund et al., 2006a; Healy et al., 2008a). This study uses less sensitive measures but they are field based and can be administered with relatively small amount of training at a population and surveillance level.
- Large scales studies have found that there is a difference in compliance rates (number of days of valid data) depending on body weight status (Troiano et al., 2008). It is important to make sure that the sample is not biased towards the seemingly healthier participants-what are the demographics of those who did not
comply? Characteristics of those who consented but did not participate or who did not consent were not available so there is no way of knowing if these students (n=12) were different or unique in some way to those who did participate. A large sample would reduce this bias towards those who participated.

8.5 Conclusions

- Other studies have shown a connection between sedentary levels and health outcomes that are independent of physical activity levels in adults. This connection was not found here but the links between body composition and sedentary time do warrant further investigation.
- This group of adolescent females accumulated more and longer bouts of sedentary activity on school days compared to weekend days. This is an important finding from a public health perspective as it seems that school inadvertently promotes a sedentary lifestyle.
- Accelerometry should be employed to measure sedentary levels as well as physical activity levels where possible. Especially as self report cannot give a complete picture of the ubiquitous activity that is sedentary behaviours.
Chapter 9

General Discussion
9.1 Introduction

In the preceding chapters a number of themes have been explored. Accelerometry validation and calibration was undertaken and results have been critically presented. Physical activity interventions were described along with the practical experiences and lessons learned. Accelerometry methodologies have been developed from chapters 4 to 7 towards achieving a best practice protocol. This culminated in the use of accelerometry with a cross-section of adolescent females in chapter 8 and the description of their sedentary patterns and physical activity levels. While the results of each chapter have been discussed individually, this chapter aims to combine all the findings and explore the overall conclusions from this Ph.D. work. Limitations of some of the work will be considered and recommendations for future work will then be suggested.

9.1.1 Equations to Estimate Intensity Using ActivPAL Outputs

Validation of the ActivPAL inbuilt algorithm that estimates metabolic equivalents (METs) had not been previously reported so this was a novel paper. Initial analyses indicated that the results using the inbuilt equation were subject to an underestimation. Therefore a new equation was developed based on data obtained under treadmill conditions. The equation was developed using a mixed model approach and by reporting a concordance correlation coefficient which is the mixed model version of an $r^2$. This is a newer approach that has been employed by Treuth et al. (2004a) and Schmitz et al. (2005) and offers a more practical and interpretable approach to validation and calibration studies (Welk, 2005). While the new adult equation was a good fit (CCC of 0.78) when it was cross-validated it was found that the new equation underestimated METs under free living conditions. This result is not unique; other studies have similarly illustrated the limitations of accelerometer thresholds when used in conditions different to the conditions they were created under. Furthermore, new calibration equations and resultant thresholds are often not cross-validated at all and are frequently used without question.

Recent reviews have suggested that thresholds should be based on data from a wide range of free-living activities. In this thesis a new equation was developed based on the free living activities described in Table 5.1, granted on 12 participants only. The
performance of these two equations in estimating moderate to vigorous physical activity (MVPA) was then compared. There were significant differences between the two equations. This finding demonstrates that a threshold based on treadmill walking and one based on free living activities produces inconsistent results and therefore caution must be used when interpreting physical activity data using various thresholds. The free living equation was based on too many diverse activities some of which an accelerometer would not be expected to detect- an elliptical and bike for example. However, to exclude these activities from the analysis would have reduced the data set to just free living walking in 12 female participants. Such an equation only changed the threshold marginally (from 1075 counts per 15 seconds to 1342 counts per 15 seconds).

9.1.2 Steps versus Counts

As mentioned above, it was reported in Chapter 5 that a treadmill equation based on counts underestimated METs when cross-validated on a free living data set. Using the same free-living data set METs were also estimated using the ActivPAL inbuilt equation, based on steps. It is possible that this may be a problem with the ActivPAL inbuilt equation rather than the accelerometer steps themselves. To investigate this, a steps based equation was derived from the same treadmill data that the adult treadmill equation (equation 5.4) was based on. In addition, as both steps and counts equations gave similar results, the extra utility of having an equation based on counts was questioned. Table 9.1 is an example of how this step based equation compared to a counts based equation when applied to free living activities as per section 5.4.3. In this the participant used an elliptical machine (minutes 30-35) and then moved into free living walking/standing/ambling around (minutes 36-45). As evident in Table 9.1, even when steps were very low, counts were still being recorded from the actions of slow ambling, standing and from the fidgeting of the leg, all of which contribute to energy expenditure. This data therefore illustrates the distinct importance of using counts based equations when estimating METs for these light intensity activities. One explanation for the differences between the two equations is that it can be difficult to calibrate steps for very low intensities as there is not enough gradation. Indeed the majority of outputs from other activity monitors are based on counts rather than steps, especially for light intensities. The use of steps may be appropriate in some circumstances since they are a
useful measure of locomotor activity. Under these conditions energy expenditure may be predicted similar to a counts based equation but will be inaccurate at lower speeds. Nevertheless, as was evident in Chapter 4, counts still maintained a stronger relationship with METs than steps did.

<table>
<thead>
<tr>
<th>Time (minute)</th>
<th>Steps (per 15 sec)</th>
<th>ActivPAL Counts (per 15 sec)</th>
<th>Criterion MET</th>
<th>Count Equation MET</th>
<th>Step Equation MET</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>30</td>
<td>5551</td>
<td>7.4</td>
<td>4.0</td>
<td>4.1</td>
</tr>
<tr>
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<td>29</td>
<td>6035</td>
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<td>4.3</td>
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</tr>
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<td>28</td>
<td>6268</td>
<td>8.4</td>
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</tr>
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<td>6072</td>
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<td>6044</td>
<td>8.9</td>
<td>4.3</td>
<td>3.8</td>
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Taken together, the results of section 9.1 would suggest that future validation research undertaken with the ActivPAL should be based on a combination of treadmill and free-living activities. If possible, any equation created should be cross-validated on the same set of participants.
9.2 Interventions

There is no doubt that there are diminishing opportunities for young people, especially adolescents to be active in their daily lives. Any type of intervention is warranted. At school, students are a ‘captive audience’ and therefore the school setting would seem to be an ideal place to intervene to increase physical activity.

Intervention one reported in Chapter 6 was seen as a pilot study and many lessons were learned. The results from interventions two and three were mixed and differed. Intervention two saw the CV fitness and physical activity of the intervention group increase significantly with no change in the control group. Intervention three had different results and saw a close to significant increase in physical activity only for the intervention group. It showed no other significant results when the intervention group was considered on its own. When the group was considered as a whole, the physical activity levels, as measured by MVPA, and CV fitness increased significantly. These results are not unique as it has been documented in the literature the lack of change that certain interventions can have, both large and small scale. These are both modest results but are in line with previous findings. For the economic and time commitment that these interventions required, the results can only been interpreted positively. There are a number of methodological reasons why no effect may have been seen in intervention three. These reasons are mainly due to the intensity of classes and duration of the intervention itself. While intensity of the classes was not measured, from the experience participants did not enjoy the activity classes run at higher intensities. Participants did not have access to showers after these classes and anecdotal evidence suggested they did not want to get sweaty and ruin their hair and makeup. This is a common barrier to PE classes cited in the literature (Taylor et al., 2000).

Intervention one took place in a co-educational school. Consultations with adolescent females in Ireland cited the presence of boys as a barrier to physical activity (McCallion, 2004). Even though boys were not present in the actual intervention classes the atmosphere in the school was particularly directed towards the male and the competitive sports. The after-school intervention classes were moved from the sports hall to the canteen space half way through the intervention. This gave the impression to the students that these types of exercise classes were not as important as the traditional
sports in the school—basketball, hockey and rugby. If this attitude continues (and prevails within the physical education context) it is no surprise that leisure time physical activity levels are dropping in the female adolescent population. Interventions two and three were run in a single sex school and there was definitely a perceived sense of more support for the girls and the intervention as a whole.

The cohorts in all the studies were in the class year called Transition Year where students ‘transition’ from a middle school to high school type setting. During this year they participate in non-academic activities and activities to promote personal development. The normal pattern of 40 minute classroom based classes may not be adhered to as the classes are often more practical in nature. The groups may actually not be as sedentary as slightly younger or older students may typically be in the school setting.

One of the key strengths of the intervention three was that the classes were independent of the normal school staff. I was not there as a disciplinarian and a good relationship was built up with the students. A future step in this direction would be to have the investigator be the facilitator for the intervention classes but not actually lead or teach the exercise classes at all. A database of qualified and suitable instructors used would need to be built up. A project like this was recommended too, and is being run by, the Local Sports Partnership.

The promotion of peer support for physical activity was not included in the interventions but research has identified a positive relationship between activity levels and peer support among adolescents (Sallis et al., 2000). This could be one reason why the control group physical activity increased along with the intervention group as those in the control group were friends with those in the intervention group. If some intervention participants were bringing about a behaviour change then they may have influenced their friends in the control group to do the same.

Although changes in the interventions seem modest on the outset, if similar improvements can be continued it would increase physical activity into adulthood. Simply exposing these students to the myriad of non-traditional, non-competitive and individual activities may mean that they take them up in their adult life. Perhaps once they go to college or get a job and have their own time and money. Lunn and Layte
(2008), in a unique analysis of Irish sporting habits called the ‘sport hill’, demonstrated that girls had the highest take-up of team sports at ages 13-14 but then quickly abandoned them by age 18 (Figure 9.1). However, approximately the same proportion took up individual sports/activities around that age but the same steep decline is not seen with individual sports. Participation in individual activities continues from late adolescence and into adulthood. The activities in the intervention were primarily individual, yet had a social element, so engaging adolescents in these should prove more successful than team sports.

Figure 9.1 Sporting hill for team and individual sports by gender. From Lunn & Layte (2008)

9.3 Use of Accelerometry with Adolescent Females

Accelerometry has been used extensively internationally to measure physical activity of all ages. To our knowledge this study was the first use of recording accelerometry in the Republic of Ireland in free living situations. Furthermore, the ActivPAL was only previously used with patient populations within a clinical setting so there was no ‘template’ of use for this device with adolescents. We found the adolescents to be very receptive to wearing the devices for a full seven days. The ActivPAL, unlike other accelerometers, is worn discreetly on the thigh without the use of belts or additional sensors. It is also light weight and overall is less invasive than other physical activity monitoring devices. Compliance with accelerometry is always a big issue and it was something that was worked on from the start. Studies have suggested that researchers
should visit schools during the 7 day period to ensure and encourage compliance (Van Coevering et al., 2005). This happened during the LPAS study (Chapter 8) as one investigator had to meet the students to administer the recall questionnaire every third day (data not shown). This could explain why compliance was higher in the LPAS study than during the intervention study. The strategies employed in the LPAS study are recommended for use and will be followed in future studies.

9.4 Physical Activity and Sedentary Levels

It was mentioned in the introduction that there has been no objective data in Ireland to confirm that adolescent females are indeed physically inactive. The data presented from this Ph.D. research should help answer the question. In Chapter 7 it was shown that only one intervention participant met the child guideline of 60 minutes MVPA on 5 or more days of the week for physical activity at pre test level (Figure 7.2). When the intervention and control groups were combined as a whole, 8 participants met the adult guideline of 150 minutes of MVPA per week and 3 met the child guidelines of 300 minutes per week (Figure 7.3). A large proportion did not meet the child or more generous adult guideline on any day. While this group were chosen for the intervention study due to their inactivity levels a similar pattern was evident in the LPAS cohort, a cohort randomly selected as a cross-section of adolescents.

Due to the large amounts of time spent by adolescents in sedentary behaviours it would seem like an important place to direct research efforts and subsequent interventions (Matthews et al., 2008). The methodology and analysis employed in chapter 8 to investigate sedentary patterns and physical activity levels differs greatly to other studies in Ireland. Consequently we have provided a unique insight into certain lifestyle habits of Irish adolescent females which before have largely gone undocumented or have been measured using flawed methodologies. We used an objective measure of physical activity and direct measure of body posture without the use of thresholds which is actually unique in the literature of adolescent health as far as we are aware. We have directly quantified sedentary behaviours over a full 24 hour period and for these reasons it is not surprising that sedentary time differs greatly to other studies (Fahey et al., 2005:74). Our results must be judged with caution due to the small sample size. However, our random
and cross-sectional sample, best practice methodologies and clear results make a good foundation for future work on sedentary measurement of all populations.

Sedentary activities track from adolescence to adulthood stronger than physical activity (Malina, 2001). As our cohort move from adolescence to adulthood the protective effect of physical activity may reduce and sedentary activities take its place. Reducing or breaking up sitting down time must be made a public health priority. This is additional, and not an alternative, to participation in MVPA. Intervention strategies to decrease the number and duration of sedentary bouts should be employed in a school based setting with more sensitive outcome measures of health.

9.5 From a National and Policy Point of View

The original studies of physical activity interventions evolved from the 2005 Irish National Taskforce on Obesity Report after it put forward many recommendations with regard to the treatment and prevention of obesity in school settings. These recommendations were echoed by Lunn and Layte (2008) three years later when they concluded that “sport and education policy makers need to look at ways to improve the range of sport offered to girls at second-level and, in particular, to provide opportunities to engage with individual sports that are more appealing.” Since the 2005 report there seems to be no consistent strategy for, or investment in, implementing these recommendations (Finucane, 2009). Assuming that it is a funding issue which has prevented the implementation of recommendations a full cost-benefit analysis of these recommendations is warranted and how much they may save on future health spending. In the UK it was estimated that physical inactivity directly cost the health service £1.06billion (Allender et al., 2007) and was responsible for 3.1% of morbidity and mortality. This cost does not include indirect costs such as loss of productivity or home care costs. Strategies to increase physical activity will have a two fold benefit (Fulton et al., 2009). Firstly it will help with weight reduction or weight maintenance and secondly increased physical fitness has an impact regardless of a person’s body composition as has been shown by Lee et al. (1999). Keeping with an economic analogy, physical activity is an investment that pays multiple health dividends (Fulton et al., 2009) and therefore long-term economic savings.
In Ireland, any physical activity promotion emanates from and is associated with the Department of Health and Children but physical activity promotion and obesity prevention should be a wider issue. Other governmental departments could work together to help this fight, to share the economic cost but also share in the benefits. Table 9.2 outlines the various Irish governmental departments and suggests ways in which they could help with the fight. There is an economic case for the prioritisation of physical activity policies and strategies (Allender et al., 2007). Government is not the only sector that can assist. The blame for the rise in obesity levels and decrease in physical activity levels is levelled at many different groups but all people have their own role to play. Funding groups, health care workers and those dealing with children, food companies and parents can all play a key role in fighting the global epidemic (Koletzko et al., 2002).

Table 9.2 Possible ways that each Irish government department can assist towards promoting physical activity and preventing obesity.

<table>
<thead>
<tr>
<th>Governmental Department</th>
<th>How</th>
</tr>
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<tbody>
<tr>
<td>Environment</td>
<td>Provision of green spaces, eco friendly transport, inclusion of sports courts, cycle lanes and safe walking areas for commuting or leisure. Urban planning which promotes health geography.</td>
</tr>
<tr>
<td>Transport</td>
<td>Promotion of cycling and safe cycle lanes.</td>
</tr>
<tr>
<td>Tourism, Culture and Sport</td>
<td>Funding for Local Sports Partnerships (LSPs), sports and recreation facilities.</td>
</tr>
<tr>
<td>Community, Equality and Gaeltacht affairs</td>
<td>Co-ordination of local programs in cooperation with the LSPs.</td>
</tr>
<tr>
<td>Education and Science</td>
<td>PE in schools.</td>
</tr>
<tr>
<td>Enterprise, Trade and Innovation</td>
<td>Third Level funding for further research</td>
</tr>
</tbody>
</table>

From a policy perspective, Scotland may be used as an example and as a blueprint for Irish efforts. In 2001, a physical activity taskforce was set up with the direction of working towards making Scotland healthier. A national physical activity policy was published in 2003 entitled ‘Let’s Make Scotland More Active’ (LMSMA) which aimed to increase and maintain the proportion of the population physically active by 2022 (Scottish Executive, 2003). Many projects and strategies come under the umbrella of this
policy. These include the funding of projects and initiatives such as Active Schools, setting up local physical activity strategies, developing supporting environments and the raising awareness of local projects and physical activity in general. A comprehensive timeline and set of goals for the first 5 years of the policy have been documented and collaborations to support the implementation of LMSMA (2003) recommendations have been set up. Another important element to the policy is research, monitoring and evaluation and the funding of same. A 5 year review evaluated LMSMAs impact on the above points (Scottish Physical Activity Review Group, 2009) and in the last few months a review of changes in Scottish physical activity levels in the past 5 years was published (Scottish Physical Activity Review Group, 2010). There is a commitment to physical activity across a wide range of sectors and through policy and planning.

9.6 Limitations

• Following the myriad of data presented in Chapter 5 no full conclusion could be drawn on which was the most appropriate equation to use if any. The adult equation underestimated while the free living equation had a small sample size. There was not an opportunity to cross-validate the adolescent treadmill based equation on some free living activities in the same population. The threshold based on the adolescent equation had to be employed on the data sets of ActivPAL data collected from pre and post intervention tests and LPAS. However, the limitations of this equation are known and accepted.

• The free living equation contained too many diverse activities that an accelerometer would not be expected to pick up- an elliptical and bike for example. That study which was based at Iowa State University was designed to validate another accelerometer which includes a physiological recording. Changes in intensity would be expected to be picked up by a device which combines acceleration and physiological data. This protocol may have resulted in a data set that was not wholly appropriate to cross-validate a treadmill equation.

• There was no mobile metabolic systems to cross-validate the adolescent treadmill equation or to create a new one using free living activities available in Limerick. The use of this as a criterion measure is a recommendation for future work.
• The intervention schools were the schools that responded to an invitation to participate and were receptive to hosting the intervention. Realistically these schools would attract students from a higher socio-economic class so the results, modest successes and broad experiences from the interventions cannot be generalised to other schools.

• Data analysis did not use any algorithm or imputation of missing data for accelerometry. This means that if a participant took off the accelerometer these data were simply deleted. This may have skewed the data in favour of participants who took off the accelerometer when they were inactive. Larger sample sizes and a robust statistical method for dealing with missing data would be advised.

• A known and accepted limitation of this form of accelerometry is that it does not detect upper body movements, it does not recognise changes in incline or cycling and the device has to be removed before swimming. This may mean that physical activity levels are higher than measured. The questionnaire for the LPAS study did not reveal any swimming or cycling (data not shown) so the effects of these are negligible. This limitation could be overcome by combining accelerometry with a physiological measure such as heart rate.

9.7 Recommendations for Future Research

• Creation of an equation based on free living and treadmill activities in adolescents using a protocol that is appropriate to the device, the population and which follows best practice recommendations. Creation of equations using a full adult spectrum of the population and a diverse range of activities. This will allow ActivPAL data from populations other than adolescent females to be interpreted with confidence.

• Larger scale investigations of sedentary and physical activity patterns of adolescent females.

• Further analysis of accelerometry data to provide separate values for time spent standing and time spent in light intensity activities.

• Retention testing and follow up of the intervention groups. While the intervention may not have had a large or significant effect on the participants current health and activity levels it may impact their future lives.
• Attention towards the school environment as a possible facilitator of sedentary activity. This would involve analysis of sedentary and physical activity levels during school hours (9-3pm) and after school hours (6-9pm). Also, school based intervention could be piloted to decrease the length and number of sedentary bouts in the 9-3 school day.

9.8 Main Conclusions

• Accelerometry based methodologies have been developed to objectively measure physical activity and sedentary levels using the ActivPAL physical activity logger. These methodologies are and will continue to be used by undergraduate and graduate students interested in measuring these variables.

• When these methodologies are employed the ActivPAL is well tolerated by adolescent females, compliance is high and would be a useful tool for use in large scale studies.

• The ActivPAL Physical Activity Logger is a valid and user-friendly tool to directly measure sedentary levels and patterns without the use of threshold.

• A school based intervention is a useful way to increase adolescents’ physical activity experiences and physical activity during the intervention. The duration may need to be longer and the intensity higher to be efficacious in changing health parameters.

• The prevalence of overweight and obesity was at the level that we expected (17-20%). Regardless of body composition, low levels of physical activity put these adolescents at risk of future diseases.

• There appears to be a link between sedentary levels and health parameters in a cross-section of adolescent females but this link is not independent of physical activity levels.

• Sedentary levels and patterns were higher on week days (school days) than at weekends. Schools inadvertently promote sedentary behaviour as students sit for long unbroken periods of time. Efforts should be directed towards classroom intervention.
Chapter 10

References


Irish Universities Nutritional Alliance (2001). *North/south Ireland food consumption survey*. Dublin: Food Safety Promotion Board


Chapter 11

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11.1 Information Sheets and Consent Forms-Validation Study
Validity and Accuracy of a Novel Physical Activity Monitor in a Female Population

What is this study about?
Physical activity has been shown to positively affect a person’s current and future health so valid, accurate and objective measures of physical activity levels and patterns are important. This study aims to validate a new accelerometer based physical activity monitor, the activPAL™ in females and to investigate if its an accurate measure of step count, cadence and predicted energy expenditure.

What will I have to do?
You will be asked to come to the University of Limerick PE and Sports Science building (Old sports building) and bring the required attire of light shorts and t-shirt and gel soled runners as opposed to flat soled fashion runners. These may all affect your ability to run efficiently. You are asked to wear similar clothing and footwear for each testing session. This is to reduce any effects that different test environments and conditions may have on the results You will sign an informed consent form and a pretest health status questionnaire. Both of these need to be signed fully before you can proceed. You will be given a 5 minutes familiarisation session on the treadmill where you will experience the different speeds and gradients that will be used in the testing. You will be encouraged to free walk/jog i.e. not holding onto the side handrails.

On the next testing day your height and weight will be taken first to calculate body mass index (BMI) which is standard procedure for this type of research. We will then assess your body composition using a 4 skinfold site technique. You will stand in the anatomical
position (standing the feet together, arms by the side with the head and palms facing forward) as we measure the way the ‘skin folds’ at four body parts. The four sites which are measured are mid –biceps (front of the upper arm), mid-triceps (back of the upper arm), sub-scapular (under the shoulder blade) and the iliac crest (side of body near hip bone). They are measured using a skinfold calipers which is a tiny gadget with two arms to place around the skinfold and a dial to tell you the measurement. One female researcher will grasp the skin and fat at a particular site using the thumb and index finger of one hand and place the arms of the calipers on either side of the drawn up tissue with the other. The calipers will be firm against the skin but not digging in. The measurement can then be read off from the tiny dial and is recorded. The procedure at each site should take no more than 15-20 seconds, but is carried out a total of three times to be sure we are correct. There will be a break between each measurement. You will only remove your top if you are wearing a long sleeved item of clothing, undergarments and short-sleeved tops can stay on. Another female will be present throughout.

You will be given a Polar heart rate monitor for the main testing. This is simply a watch on your wrist which picks up a signal from a strap fitted around your chest (around the area of your bra strap). It might be a bit uncomfortable at first but once you start exercising it you will be used to it. You will also be asked to wear two commercially available accelerometers. One on the midline of your thigh and the other attached to your waistband. The activPAL will be on the thigh will be attached with a hypoallergenic stickie which keeps it firmly in place. A video camera will record the steps you take from a 90º by your feet. Your identity will not be recorded.

For the main test you will asked to walk and jog for 6 minutes each at 3.2 km/h, 4 km/h, 4.8 km/h (slow walk), 5.6 km/h, 6.4 km/h (fast walk), 7 km/h and 8.1 km/h (jog) in line with previous research and at a gradients 0%, 3% and 6%. Rest for 2 minutes between each section (or as long as it takes for heart rate to return to baseline). After 3 minutes at each speed a snorkel type mouthpiece will be placed in your mouth and you will continue to breath as normal. This allows us to collect and analyse the different levels of oxygen and carbon dioxide that you exhale. From that we can calculate energy consumption and the rate of fat burning. This will only be recorded for the last two minutes at each speed. You will be asked to point to a rate perceived exertion (RPE) scale to tell us who hard you think you are working in the last minute at each workload.

You will be free to stop the testing whenever you want if you feel too tired, you get very out of breath or you get pains in your legs.
What are the Benefits of this Project?
You will receive a copy of your skinfold and treadmill testing results that could be of benefit to you and inform you of your body composition and energy consumption. For example you will be able to see what effect increasing the gradient has on your fat burning and overall energy usage. This could be useful if you regularly walk or jog or are thinking of beginning to walk for leisure.
You will not be informed directly of the overall results of this research study. However, it is hoped that the results of this study will give us a greater understating of the uses and accuracy of the activPAL physical activity monitor in a female population.

What are the risks?
The UL Research Ethics Committee has assessed all risks associated with each testing procedure.
As with all forms of exercise this is a risk of injury to participants. This includes but is not restricted to strains, sprains and overuse injuries or falling off the treadmill. To reduce these risks you will have a familiarisation session and a full set of warm up and cool down stretches.

What are the alternatives?
Not applicable

What if I do not want to take part or change my mind during the study?
Your participation is completely voluntary so you should not feel pressurised into taking parting and/or continuing in the study. You are free to drop out at any time and do not have to provide us with a reason.

What happens to the information?
All information gathered is highly confidential and will be stored under secure conditions. You should be aware that the data gathered might be used in a Postgraduate thesis but at no stage will names or any personal details be disclosed.

Who else is taking part?
Other females in the 18-24 age bracket from the UL campus community

What if something goes wrong?
In the event of an emergency we have protocol in place to deal with such an emergency.
What if I have more questions or do not fully understand something?
If you would like to know more about your role in this study, please do not hesitate to contact the investigators listed below.

Contact details of investigators:

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Contact No.</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ms. Deirdre Harrington</td>
<td>Postgraduate Student</td>
<td>086-3196816</td>
<td><a href="mailto:deirdre.harrington@ul.ie">deirdre.harrington@ul.ie</a></td>
</tr>
<tr>
<td>Dr. Alan Donnelly</td>
<td>Supervisor</td>
<td>061-202808</td>
<td><a href="mailto:alan.donnelly@ul.ie">alan.donnelly@ul.ie</a></td>
</tr>
</tbody>
</table>

If you have any concerns about this study and wish to contact someone independent, you may contact:

The Chairman of the University of Limerick Research Ethics Committee
c/o Vice President Academic and Registrar’s Office
University of Limerick
Limerick
Tel: (061) 202022
Participant Informed Consent Form

Validation of a Novel Physical Activity Monitor in a Female Population

Please read the following statements:
- I have read and understood the participant information sheet.
- I understand what the project is about, and what the results will be used for.
- I am fully aware of all of the procedures involving myself, and of any risks and benefits associated with the study.
- I know that my participation is voluntary and that I can withdraw from the project at any stage without giving any reason.
- I know that my results will be kept confidential

By signing below you are agreeing to the above statements and giving informed consent for you to participate in the above study.

Signed: _________________________________

Print Name: _____________________________

Date: ___________
Are you:

xFB Female?
xFB Aged between 18 and 24?
xFB Interested in taking part in a UL study to help us understand different physical activity monitors?
xFB Interested in finding out some unique information on your energy consumption and the amount of fat you burn at different walking speeds and at different gradients?  

If so, this study is for you!

All you will need to do is walk and jog at a variety of different speeds and gradients for 6 minutes each while your oxygen and carbon dioxide production is recorded from a snorkel type mouthpiece in your mouth. Speeds ranging from 3.2km/h (very slow walk) to 6.4km/h (medium walk) to 7km/h (slow jog) will be used and you will get to rest between each one. You will never be working maximally and have the option to stop at any of the speeds at any time.

Your involvement will be 2 sessions over the space of 1 week. The first session is a brief familiarisation and will last 15mins and the second is the main session and will last 1hr and 45mins. The testing will fit in with your schedule!

If you’re a competitive athlete or train more than 3 times per week then this study is not quite for you, but thanks for your interest!

If you are interested please email deirdre.Harrington@ul.ie  Places are limited though so act fast! Approval has been granted by the Physical Education and Sports Science Ethics Committee. PESSREC Number 44/07

For more information or questions contact the investigators:

<table>
<thead>
<tr>
<th>Name</th>
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<td><a href="mailto:alan.donnelly@ul.ie">alan.donnelly@ul.ie</a></td>
</tr>
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</table>
11.2 Participant and Parent/Carer Information Sheets and Consent Forms-Interventions
Mr. A. Principal,
Some Secondary School,
Limerick

Dear Principal,

My name is Deirdre Harrington and I am a graduate of Sports and Exercise Science from the University of Limerick. I am currently undertaking a research Masters here in UL under the supervision of Dr. Alan Donnelly (Head of Department of Physical Education and Sports Sciences). My area of research is the relationship between health, fitness and physical activity with particular interest in adolescent girls. The aim of my research is to discover the effects of a 12-week physical activity intervention on the health and fitness of adolescent girls (transition/5th years).

At this first stage I am writing to a number of Limerick schools looking for an expression of interest with the ultimate goal of recruiting a suitable school to partake in this study. It is envisaged that the study will start this September with the intervention running over 12 consecutive weeks (mid-term and Christmas holidays are the exception). Some of the particulars of the study are outline in the attached document.

Partaking in this study is a unique opportunity and will offer many benefits to your students. Not only will the chosen school be helping greatly in the understanding of adolescent health and fitness but will also be able to host free, 4 time per week exercise classes for the participating female students. This exercise class, which will be geared towards teenage girls will not be like a standard PE class and will allow the girls to experience physical activity that they may not have access to normally. Students in exercise and control groups will also be able to receive information on physiological measures of their fitness, and on their body composition.

University of Limerick
OLLSCOIL LUIMNIGH
There has been a lot of talk in the media of late about the so called ‘obesity epidemic’ and the health and fitness of our young people, particularly teenage girls. A lack of physical activity that is non-competitive, popular and fun has been blamed and this is where my project comes in. This exercise will be fun, safe (conforming to all exercise to music standards) and will produce effects that will impact on the girls’ current and future health.

I would appreciate if you would discuss this opportunity with the pertinent faculty members and return the Expression of Interest form by xxx 2006. Once I receive this form I will contact you and arrange a meeting where we can discuss the project in more detail, your female student population and all the other issues which might arise. The final school will then be chosen using a set of pre-established criteria.

If you have any questions or require further information about the project and your possible role in it do not hesitate to contact me or my project supervisor (details attached).

In expressing interest in this project you are taking the first proactive step in helping to change the health of your students and impacting on their lives.

Yours Sincerely,

___________________________________
Deirdre Harrington BSc (Sports Science)

___________________________________
Dr. Alan Donnelly (Head of Department of Physical Education and Sports Sciences)
Physical Activity Monitoring using Accelerometry

Following on from the previous Information sheet, it is necessary to quantify the whole class physical activity levels before and after the exercise intervention. This is called accelerometry and is done using an accelerometer called an activPal. The activPal is a tiny, lightweight box that measures the amount and direction of all the activity that one does during the normal day. It can tell how long one spends lying, standing and walking and how fast one walks (by the number of steps that one takes). The accelerometer will be worn of the mid part of the front of the thigh (under clothing) and is held on by a ‘stickie’. This 'stickie' is skin and hair friendly and can be used multiple times. It is non invasive and will not impede your daughters normal daily activities. It only needs to be removed before bathing and before any water based activities.

Your daughter will wear this activPal for 5 days including 2 weekend days so we can get an overall picture of her physical activity patterns and levels. Each participant is free to not wear the accelerometer if they feel uncomfortable in any way and can return it before the 5 days are up. This will not affect their future treatment or participation in the main project. Benefits and risks are as per previous information sheet.
Parent/Carer Informed Consent Form

Physical Activity Monitoring using Accelerometry

Please read the following statements:

- I have read and understood this additional parent/carer information.
- I am fully aware of the procedures involving my child, and of any risks and benefits associated with the study.
- I know that my child’s participation is voluntary and that I can withdraw her from the project at any stage without giving any reason.
- I know that my child can withdraw from the project herself at any time without giving any reason.
- I am aware that my results will be kept confidential

By signing below you are agreeing to the above statements and giving informed consent for ____________________________ to participate in the above section of the study.

Signed: ________________________________

Relationship to the participant: ______________________

Date: ___________

University of Limerick
OLLSCOIL LUIMNIGH
11.3 Limerick Physical Activity Study Documentation
Parent/Carer Informed Consent

I have read and understand the parental information sheet and have had due time to consider it. I now fully understand the purposes of the project: *The Limerick Physical Activity and Fitness Study of Adolescent Girls*, and what the data will be used for. I am fully aware of the procedures that will involve my child, and I am aware that she can withdraw from this project at anytime, and that her participation is completely voluntary. She will not have to give any reasons as to why she leaves the study if she so chooses to. I am aware that her results will be completely confidential.

I________________________, understand all that is involved in this study. I hereby agree to allow my child to take part in this research project.

Signed: __________________________

Relationship with the participant: __________________________

Date: __________________________
What is the project about?
Regular physical activity during childhood and adolescents is associated with improvements in many physical and psychological health benefits, such as reducing risk of obesity, cardiovascular disease, non-insulin-dependant diabetes, osteoporosis, certain cancers and depression. Regular physical activity is characterised by taking part in moderate intensity activity for 30 minutes a day 5 times a week or by doing vigorous intensity cardiorespiratory fitness work for 20 minutes at least 3 days a week. Although these target appear very achievable, studies show that many Irish adolescents, particularly females, fall short of the prescribed amount of physical activity to maintain a healthy lifestyle.

This study aims to assess participation levels in physical activity in a broad group of female adolescents in the Limerick area. The study will examine these participation levels, and will compare results with prescribed physical activity levels and with other Irish studies findings.

What will your child have to do?
The first set of tests will be physiological testing. These will take place in an appropriately private space with another female observer present at all times to ensure the safety and protection of both the participants and researchers involved. Height and weight will be measured in stocking feet, light shorts and t-shirt by a female researcher. This will provide us with the information necessary for calculating BMI (Body Mass Index). Measurement of the waist and hip of your daughter will then be taken. The next body composition test is the 4 site skinfold test. The four sites measured are mid-biceps (front of upper arm), mid-triceps (back of the upper arm), sub-scapular (under the shoulder blade) and the iliac crest (side of the body, near the hip bone). All measurements will be taken using a skinfold caliper, and will be performed by an experienced female researcher. Finally, blood pressure will be measured using a standard procedure. The appropriately sized cuff will be placed around the upper arm and inflated automatically. The pressure will be slowly reduced, and both systolic and diastolic blood pressures will be recorded.
On completion of the physiological tests, your daughter will be asked to take part in a 20 meter shuttle run test (more commonly known as a Bleep test). This is a standardized test to measure cardio respiratory fitness in large groups. This is a non invasive test, which will involve your daughter running up and down a 20 meter track at specific paces for as long as they can. Your daughter will have the option of dropping out of this test whenever they feel they cannot go any further. This test can last up to 20 minutes, and will be carried out in the school gymnasium.

Physical Activity Levels will be monitored the week preceding this testing. This is called accelerometry, and is carried out using an accelerometer called an ActivPal. The ActivPal is a tiny, lightweight box that measures the amount and direction of all the activity that one does. It can tell how long one spends sitting, standing, lying and stepping, and how fast one walks/jogs/runs. The accelerometer is worn on the mid part of the front of the right thigh, and is held onto the skin with a hypoallergenic stickie. This stickie is both hair and skin friendly. This form of testing is neither invasive, nor will it impede your daughters everyday life. The ActivPal only needs to be removed before bathing and any water based activities. The ActivPal will be worn for 7 days, including 2 weekend days so we can get any overall picture of her physical activity patterns. Each participant is free to not wear the accelerometer if they feel uncomfortable in any way and can return it before the 7 days are up. This will not affect their future treatment or participation.

Finally, on return of the accelerometers, your daughter will be asked to complete a Physical Activity questionnaire. This questionnaire will inform us of your daughters perceived activity rates during the same week in which they wore the accelerometer. This allows us to compare the actual level of physical activity to how active your daughter believes she is.

What are the benefits to your child?
Your daughter will receive a copy of her results, which can inform them of their body composition and cardiovascular fitness. You or your daughter will not be directly informed of the results of this research study. However, it is hoped that the results of this research will inform us of the physical activity levels and physical fitness levels of a broad, random group of female adolescent girls in the Limerick region.

What are the risks?
The UL research Ethics Committee has assessed all risks associated with each testing procedure. All researchers will be appropriately qualified for all testing in the study.
What if my child does not want to take part?
We are very appreciative of everyone’s time, including your time in reading this consent form. However if your child does not wish to take part in the study, it is entirely their decision. They may withdraw from the study at any time and we will thank them for their time and help.

Who else is taking part in this Research Project?
It is hoped that 15 other participants from your child’s school will take part in this study, and 90 other participants from other schools around Limerick will also be tested.

What happens to the information that is gathered?
The information is completely confidential and will only be used for the purpose of this project. Only the people involved in this project will have access to the questionnaires and results of the testing. Once the project is complete, all personal information will be destroyed. Remaining data will be retained for the recommended period of 7-10 years.

Who can I contact for additional information?
If you would like to know more about this study, please do not hesitate to contact any of the investigators listed below.

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Contact No.</th>
<th>E-mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ms. Deirdre Harrington</td>
<td>Postgraduate Student</td>
<td>086-3196816</td>
<td><a href="mailto:deirdre.harrington@ul.ie">deirdre.harrington@ul.ie</a></td>
</tr>
<tr>
<td>Mr. Kieran Dowd</td>
<td>Postgraduate Student</td>
<td>087-9126217</td>
<td><a href="mailto:kieran.dowd@ul.ie">kieran.dowd@ul.ie</a></td>
</tr>
<tr>
<td>Prof. Alan Donnelly</td>
<td>Senior Lecturer</td>
<td>061-202808</td>
<td><a href="mailto:alan.donnelly@ul.ie">alan.donnelly@ul.ie</a></td>
</tr>
</tbody>
</table>

Also if you have concerns about this study and wish to contact someone independent, you may contact:
The Chairman of the University of Limerick Research Ethics Committee.
C/o Vice President Academic and Registrar’s Office
University of Limerick
Limerick
Tel: (061) 202022
I have read and understand the subject information sheet and have had due time to consider it. I now fully understand what this project: *The Limerick Physical Activity and Fitness Study of Adolescent Girls* is all about and what the data will be used for. I am fully aware of the procedures involving myself that are involved in this project. I am aware that I can pull out of this project at anytime, and that my participation is completely voluntary. I do not have to give any reasons as to why I leave the study if I so choose to. I am aware that my results will be completely confidential.

I __________________, understand all that is involved in this study. I hereby agree to take part in this research project.

Signed: ____________________________________________

Date: _______________________________________________

WITNESS SIGNATURE:

Signed: ____________________________________________

Date: _______________________________________________
The Limerick Physical Activity and Fitness Study of Adolescent Girls

What is the project about?
Regular physical activity during childhood and adolescents is associated with improvements in many physical and psychological health benefits, such as reducing risk of obesity, cardiovascular disease, non-insulin-dependant diabetes, osteoporosis, colon cancer and depression. Regular physical activity is characterized by taking part in moderate intensity activity for 30 minutes a day 5 times a week or by doing vigorous intensity cardiorespiratory fitness work for 20 minutes at least 3 days a week. Although these target appear very achievable, studies show that many Irish adolescents, particularly females, fall short of the prescribed amount of physical activity to maintain a healthy lifestyle.

This study aims to assess participation levels in physical activity in a broad group of female adolescents in the Limerick area. The study will examine these participation levels, and will compare results with prescribed physical activity levels and with other Irish studies findings.

What will you have to do?
The first type of testing you will take part in is the physiological testing. This will take place in a private space with a female tester and another female observer will be present at all times. At no point will you be on your own with the people carrying out the tests. Height and weight will be measured in stocking feet, light shorts and t-shirt by the female researcher. This will provide us with the information necessary for calculating BMI (Body Mass Index). Measurement of your waist and hip will then be taken. The next test is the 4 site skinfold test. The four sites measured are mid-biceps (front of upper arm), mid-triceps (back of the upper arm), sub-scapular (under the shoulder blade) and the iliac crest (side of the body, near the hip bone). All measurements will be taken using a skinfold caliper, and will be performed by an experienced female researcher. The procedure should take no more then 15-20 seconds at each site, but each measurement has to be taken 3 times, to ensure the right result is received. Finally, blood pressure will be measured using a standard procedure. The appropriately sized cuff will be placed around the upper
arm and inflated automatically. The pressure will be slowly reduced, and both systolic and diastolic blood pressures will be recorded.

On completion of the physiological tests, you will be asked to take part in a 20 MST (20 meter shuttle run test aka. Bleep test). This is a standardized test to measure cardio respiratory fitness in large groups. This is a non invasive test, which will involve running up and down a 20 meter track at specific paces for as long as you can (Many P.E teachers use this as a test in schools, and you may have already completed a bleep test in your current school). You will have the option of dropping out of this test whenever you feel that you cannot go any further. This test will last between 15 and 20 minutes, and will be carried out in the school gymnasium.

Physical Activity levels will be calculated the week after this testing. This procedure is called accelerometry, and is carried out using an accelerometer called an ActivPal. The ActivPal is a tiny, lightweight box that measures the amount and direction of all the activity that one does. It can tell how long one spends sitting, standing, lying and walking, and how fast one walks. The accelerometer is worn on the mid part of the front of the right thigh, and is held onto the skin with a hypoallergenic stickie. This stickie is both hair and skin friendly. This form of testing is neither invasive, nor will it impede your everyday life. The ActivPal only needs to be removed before bathing and any water based activities. The ActivPal will be worn for 7 days, including 2 weekend days so we can get any overall picture of your physical activity patterns. Each participant is free to not wear the accelerometer if they feel uncomfortable in any way and can return it before the 7 days are up. This will not affect your future treatment or participation.

Finally, on return of the accelerometers, you will be asked to complete a self report questionnaire. This questionnaire will inform us of your perceived activity rates during the same week in which you wore the accelerometer. This allows us to compare the actual level of physical activity to how active your daughter believes she is.

**What are the benefits to you?**

You will receive a copy of your results, which can inform you of your body composition and cardiovascular fitness. You will not be directly informed of the results of this research study. However, it is hoped that the results of this research will inform us of the physical activity levels and physical fitness levels of a broad, random group of female adolescent girls in the Limerick region.

**What are the risks?**

The UL Research Ethics Committee has assessed all risks associated with each testing procedure.
What if I do not want to take part?
We will be delighted with you taking part in the study. However if you do not wish to take part it is entirely up to you. You can withdraw from the study at any time and we will thank you for your time and help.

Who else is taking part in this Research Project?
It is hoped that 15 other participants from your school will take part in this study, and that 90 other transition year students from schools around Limerick will also participate.

What happens to the information that is gathered?
The information is completely confidential and will only be used for the purpose of this project. Only the people involved in this project will have access to the questionnaires and results of the testing. Once the project is complete, all personal information will be destroyed. Remaining data will be retained for the recommended period of 7-10 years.

What if something goes wrong?
In the event of an emergency we have protocol in place to deal with such an emergency.

Who can I contact for additional information?
If you would like to know more about this study, please do not hesitate to contact any of the investigators listed below.

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Also if you have concerns about this study and wish to contact someone independent, you may contact:

The Chairman of the University of Limerick Research Ethics Committee.
C/o Vice President Academic and Registrar's Office
University of Limerick
Limerick
Tel: (061) 202022
The Limerick Physical Activity and Fitness Study of Adolescent Girls

Should you agree to your schools participation in the above study please sign the consent form below.

I consent to the involvement of this Secondary school in this research project.

Name: (please print): __________________________(Principal)

Signed: __________________________

Date: __________________________
Dear Principal,

I am making contact with you to discuss the possibility of administering a research study in your Secondary School. A key area of research interest in the Department of Physical Education and Sport Sciences at the University of Limerick is physical activity levels of female adolescents, particularly in transition year students. Regular physical activity during childhood and adolescence is associated with improvements in numerous physiological and psychological variables such as reducing risk of obesity, cardiovascular disease, non-insulin-dependant diabetes, osteoporosis, certain cancer and depression. According to the American College of Sports Medicine guidelines, regular Physical Activity is characterised by taking part in moderate intensity activity for 30 minutes a day 5 times a week or by doing vigorous intensity cardiorespiratory fitness work for 20 minutes at least 3 days a week.

Despite the recommendations for adequate Physical Activity in adolescents being well documented, data indicates that youths become less physically active between puberty and age 18. Irish and international identifies that the dropout from participation in Physical Activity in adolescents is an area that requires more accurate and in depth investigation. However this data may be problematic due to data collection methodologies. These studies used recall questionnaires/telephone questioning to assess levels of Physical Activity. These methodologies may result in inaccurate activity scores being calculated, or incorrect levels of activity being provided to the examiner. This in turn may provide higher or lower levels of activity then were actually achieved by the participants.

The purpose of the proposed research is to investigate daily Physical Activity levels of adolescents females in Limerick using accelerometry (the gold standard in measuring Physical Activity), and comparing the results with prescribed levels of Physical Activity. The study also aims to use BMI (Body Mass Index) and skinfold measurements, along with a 20 meter endurance shuttle run test (bleep test) to compare levels of Physical Activity with physiological fitness and body composition. The accelerometry results will also be compared with self perceived Physical Activity levels, calculated from a validated questionnaire.
The purposes of the proposed study are as follows:

- To establish the Physical Activity rates of 15-16 year old adolescent females.
- To examine the weight profiles of students using basic anthropometry, height and weight (Body Mass Index test) and skinfold test.
- To establish the cardiovascular fitness of the participants using the 20 meter shuttle run test (Bleep test).
- To test the participants blood pressure using a standard blood test procedure.
- To administer a recall questionnaire to investigate the accuracy of self perceived physical activity and actual physical activity recorded from the accelerometers.
- To examine the interrelationships that exists among the measured variables.

A total sample base of 100 transition year students from schools around Limerick will be required for the study. However, only a random sample of 15 students from your school is required. If you agree to participation in the study, a list of all children who fit the inclusion criteria will be required and from this list, participants will be selected. Participation in the study will be subject to ethics approval, and the consent of parents and participants.

Deirdre Harrington and Kieran Dowd, both PhD students in the University of Limerick, will assist in administering the study. They will require some assistance from a class teacher in the administration of the study. Additionally, I will closely monitor the study. If you require more in-depth information about the study and the procedures I would be happy to speak with you or forward you on this information.

Please find enclosed an informed consent form for your signature should you agree to your schools participation. If you have any queries please do not hesitate to contact me. The study promises to be of great benefit for the participants and they will experience no discomfort. I will be in touch with you shortly to enquire whether you are interested in your schools involvement in this study.

Yours sincerely,

Prof. Alan Donnelly
PESS Department
University of Limerick
☎ (061) 202808 ☐ Alan.Donnelly@ul.ie
11.4 Acceptance of UL Child Protection Guidelines
Acceptance of the University of Limerick Child Protection Guidelines

I have read the University of Limerick Child Protection Guidelines and agree to abide by its contents. There is no reason why I would be considered unsuitable to work with children or young people.

Signature: _______________________________ Date: ____________

Print Name: ______________________________

Department: ______________________________
11.5 ActivPAL Manual for student participants
This is an activPal accelerometer and it is a tiny, lightweight gadget that measures the amount and direction of all the activity that you do during your normal day. It can tell how long you spend lying, standing and walking and how fast you walk (by the number of steps you take). The accelerometer is worn on the mid part of the front of your thigh and is held on by a 'stickie'. This stickie is skin and hair friendly and can be used multiple times.

**What Do I Do?**

**Day One**

The accelerometer will be attached to your thigh using a stickie and a standard tube grip bandage. Remove the plastic layer from the stickie and attach the firmly to the back of the activPAL. Then, remove the butterfly tabs and apply straight onto the skin and press in firmly. Next, take a small portion of the adhesive fabric and stick over the activPAL. Try to envelope the gadget so it is securely attached on from all sides. You can partake in all activities (except water based activities) as normal as the accelerometer is secure and should not impede your normal activity.

Once you leave school I would ask you to leave the accelerometer on all day and all night except when you’re are bathing, swimming or doing any other water based activities. When bathing, remove the fabric, activPAL and stickie and leave in a flat, dry, safe place. Try not to use any moisturising or other creams on the area where the activPAL will be stuck as this can make the stickie less sticky! Once you are dried off reattach the activPAL using the same stickie. You can replace the fabric if necessary.

Record on the activPAL diary sheet the time and day when you took off and put back on the activPAL. Otherwise when you have it off I will think you were lying down!!
Day Two to Five and Weekend

Again I would remind you to remove the activPAL before bathing but reattach as soon as you can afterwards once you have dried off. The same stickie may be used again. But don’t forget to record the time and day you took it off and put it back on. Go about your normal day!

FAQs

Where should I apply the activPAL?

It is most comfortable to wear the activPAL on the mid line of the thigh, about one third of the way down between the hip and the knee. However, it will work correctly anywhere on the front of the thigh as indicated on the front panel of the device.

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 as well if any lotions (moisturiser or fake tan for example) are on the leg. Often the stickie on its own is not secure enough especially during some more vigorous activities. Add the tube grip bandage over the activPAL making sure to create an envelope with the fabric all around the activPAL.

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—it will flash green every six seconds. If it is not flashing green please ring me!

**Are there any safety issues or warnings?**

Ensure to dry off thoroughly after bathing before reapplying the activPal. If it drops or falls from the leg don’t worry—just check the front panel to see if the little green light flashes every 6 seconds. Security wise, please don’t leave the activPal lying around in school or public toilets or showers in case it gets lost or stolen. Each activPal is not cheap so it is essential that you know where it is at all times!

**What if I’m in trouble 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 me 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.

Mobile: 086-319xxxx email: deirdre.Harrington@ul.ie

“Once again, thank you for all your help and co-operation!”
11.6 Timetable of Intervention Two
<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Date</th>
<th>Activity</th>
<th>Date</th>
<th>Activity</th>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (5 Sep)</td>
<td>Introduction to the project.</td>
<td>2 (12)</td>
<td>Accelerometry number 2</td>
<td>3 (19)</td>
<td>Accelerometry number 3.</td>
<td>4 (26)</td>
<td>Exercise Class</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>(3) No class due to Junior Cert Results</td>
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<tr>
<td>Fri</td>
<td>Pre testing. 20 MST, skinfolds and BMI</td>
<td>Double Pretesting</td>
<td>Physiology</td>
<td>Accelerometry 2nd 3</td>
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<td></td>
</tr>
<tr>
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<td>INSTRUCTOR</td>
<td>Class</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>Class</td>
<td>Class</td>
<td>Class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fri</td>
<td>Class</td>
<td>INSTRUCTOR</td>
<td>Class</td>
<td>INSTRUCTOR</td>
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<td>10 (7)</td>
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<td></td>
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<td></td>
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<tr>
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<tr>
<td>13 (28)</td>
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<td>15 (12)</td>
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<td>16 (19)</td>
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<td>Class</td>
<td>Mid Intervention</td>
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<td>Work Experience</td>
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<tr>
<td>Fri</td>
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<td>20 (16)</td>
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<td>28 (12)</td>
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</tr>
<tr>
<td>Class</td>
<td>Class</td>
<td>Charity Run Details, application forms, t-shirts</td>
<td>Absent</td>
<td>Easter</td>
<td>Easter</td>
<td></td>
<td></td>
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<tr>
<td>-------</td>
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<td>Gym Visit</td>
<td>University Arena Gym Visit</td>
<td>Class</td>
<td>Easter</td>
<td>Easter</td>
<td></td>
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</tr>
<tr>
<td>31 (2 April)</td>
<td>32 (9)</td>
<td>33 (16)</td>
<td>34 (23)</td>
<td>35 (30)</td>
<td>36 (7 May)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INSTRUCTOR**

- Last minute organisation for the Charity Run tomorrow

**INSTRUCTOR**

- Lifestyle Edu

- Absent

- Class

- Post Test

- Post Test (C)

- Awards, Presentation of Sponsorship Money to the Charity
11.7 Timetable of Intervention Three
Number of classes in Intervention Three and a breakdown of what happened in each class

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity classes taken by the Lead Investigator</td>
<td>41</td>
</tr>
<tr>
<td>Activity classes taken by Community Instructor</td>
<td>21</td>
</tr>
<tr>
<td>Education classes</td>
<td>5</td>
</tr>
<tr>
<td>Gym Visits</td>
<td>4</td>
</tr>
<tr>
<td>Aqua Aerobics</td>
<td>2</td>
</tr>
<tr>
<td>Class Cancelled (1 weather, 1 illness)</td>
<td>2</td>
</tr>
<tr>
<td>School issue (4 hall unavailable, 5 other commitments)</td>
<td>9</td>
</tr>
</tbody>
</table>

Timetable of Intervention 3 including breaks in the intervention due to holidays and other school commitments

<table>
<thead>
<tr>
<th>Dates</th>
<th>Description</th>
<th>Number of Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Sept-19th Sept 2008</td>
<td>Pre Testing</td>
<td>3</td>
</tr>
<tr>
<td>15th Sept-24th Oct</td>
<td>Intervention</td>
<td>6</td>
</tr>
<tr>
<td>27th -31st Oct</td>
<td>Midterm</td>
<td>1</td>
</tr>
<tr>
<td>3Nov-12th Dec</td>
<td>Intervention</td>
<td>6</td>
</tr>
<tr>
<td>15th Dec-19th Dec</td>
<td>Work Placement</td>
<td>1</td>
</tr>
<tr>
<td>22nd Dec-7th Jan 2009</td>
<td>Xmas</td>
<td>3</td>
</tr>
<tr>
<td>7th Jan-13th Feb</td>
<td>Intervention</td>
<td>6</td>
</tr>
<tr>
<td>16th-20 Feb</td>
<td>Midterm</td>
<td>1</td>
</tr>
<tr>
<td>23rd-3rd April</td>
<td>Intervention</td>
<td>6</td>
</tr>
<tr>
<td>6th April-17th April</td>
<td>Easter</td>
<td>2</td>
</tr>
<tr>
<td>20th April-15th May</td>
<td>Intervention</td>
<td>4</td>
</tr>
<tr>
<td>11th May-22nd May</td>
<td>Post Testing</td>
<td>2</td>
</tr>
</tbody>
</table>

Total Duration of Intervention 36
Total Weeks the Intervention Ran 28
11.8 ActivPAL Graphical Outputs

11.9 Activity Profiles Using ActivPAL Graphical Output
Screen shots of the ActivPAL outputs

View by Hour
- Graphical display
- Steps per hour
- Minutes spent
- Sit/lie
- Stand
- Step

View by day
- Graphical display
- Steps per day
- Hours spent
- Sit/lie
- Stand
- Step
(1) Sedentary School Day

(2) Inactive School Day

(3) Active (30 Mins MVPA) and Sedentary (4) Active and not Sedentary
11.10 Mixed Model Description
MIXED MODEL DESCRIPTION

\[ y_i = X_i \beta + Z_i \nu_i + \epsilon_i \]

The \( n_{i} \times 1 \) response vector \( y \) for individual \( i \) is given in (5.1) with \( i = 1 \ldots N \) individuals and \( j = 1 \ldots n_{i} \) observations for individual \( i \). \( y_{i} \) is the \( n_{i} \times 1 \) dependent variable vector for individual \( i \), \( X_{i} \) is the \( n_{i} \times p \) covariate matrix for individual \( i \), \( \beta \) is the \( p \times 1 \) vector of fixed regression parameters, \( Z_{i} \) is the \( n_{i} \times r \) design matrix for the random effects, \( \nu_{i} \) is the \( r \times 1 \) vector of random individual effects, and \( \epsilon_{i} \) is the \( n_{i} \times 1 \) error vector (Hedeker & Gibbons, 2006).
11.11 Gym Permission Slips
Dear Parent(s)/Guardian(s)

As part of the Transition Year Class UL Fitness and the project “Changes in Physical Fitness and Physical Activity Levels Following an Activity and Lifestyle Education Programme” I wish to take the students on a further two trips to two local gyms. This will give the students an idea of different gym set-ups and allow them to have full use of the machines for the allocated time.

The outings will take place on Friday 15th and 29th Feb to Euphoria gym, Punches Cross, and on the 7th of March to the University of Limerick Arena. The students will walk to and from the gym for the first two trips and will be bussed to and from the gym (using University Approved Mike Hynan Coaches). Students will leave at 10.15am and return at 12pm.

If you wish for your daughter to go on these outings, please sign the permission slip below and return it to me.

Yours sincerely,

Deirdre Harrington
Deirdre Harrington  Postgraduate Researcher and Fitness Instructor

I give my daughter _____________ class _____________ permission to go on the outings on
Friday 15th Feb                  Signed: _________________________
Friday 29th Feb                 Signed: _________________________
And Friday 7th March           Signed: _________________________
11.12 Physical Activity Questionnaires
Adolescent Physical Activity Measure

Please read the following instructions carefully and answer the two questions below. If you have any questions at all please ask!

“Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time.”
“Physical activity can be done in sports, playing with friends, or walking to school.”
“Some examples of physical activity are brisk walking, jogging, rollerblading, cycling, dancing, basketball, hockey, swimming and football.”
Add up all the time you spend doing physical activity each day but DO NOT include any Physical Education (PE) classes.

Q1 Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day? (Please circle)

0 1 2 3 4 5 6 7
Days Days Days Days Days Days Days Days

Q2 Over a typical or usual week, on how many days are you physically active for a total of at least 60 minutes per day?

0 1 2 3 4 5 6 7
Days Days Days Days Days Days Days Days

Thank you for your time!

Q1 + Q2 / 2 = PAL

___ + ___ / 2 = ___
Questions on TV viewing and computer gaming from the Limerick Physical Activity and Lifestyle Questionnaire

Question 8

How many hours A DAY do you usually watch TV? (on average)

Not at all [ ] 2-3 hours [ ]
Less than half an hour a day [ ] 4 hours [ ]
Half an hour to 1 hour [ ] More than 4 hours [ ]

Question 9

How many hours A WEEK do you usually play computer games? (on average)

Not at all [ ] 4-6 hours [ ]
Less than 1 hour a week [ ] 7-9 hours [ ]
1-3 hours [ ] More than 10 hours [ ]
11.13 Cardiovascular Fitness Test Protocols
# Cardiovascular Fitness Test Protocols

<table>
<thead>
<tr>
<th>STAGE</th>
<th>DURATION (min)</th>
<th>TOTAL TIME</th>
<th>SPEED (mile/h)</th>
<th>GRADE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>6</td>
<td>1.7</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>9</td>
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<td>12</td>
</tr>
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<td>4</td>
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<td>5</td>
<td>3</td>
<td>18</td>
<td>4.2</td>
<td>16</td>
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<td>6</td>
<td>3</td>
<td>21</td>
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<td>18</td>
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**MODIFIED BRUCE**
<table>
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<tr>
<th>Duration</th>
<th>Stage</th>
<th>Speed (mph)</th>
<th>Grade (%)</th>
<th>Heart Rate (BPM)</th>
<th>RPE</th>
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<tbody>
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<td>2</td>
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<td>1.1</td>
<td>1.1</td>
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<td></td>
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<tr>
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<td>1.2</td>
<td>4</td>
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</tr>
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<td>2.5</td>
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<td>2.5</td>
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85% Max Karvonen =
<table>
<thead>
<tr>
<th>Duration</th>
<th>Stage segment</th>
<th>Speed (mph)</th>
<th>Grade (%)</th>
<th>Heart Rate (BPM)</th>
<th>RPE</th>
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<tbody>
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<td>14</td>
<td></td>
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</tr>
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<td>14</td>
<td></td>
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</tr>
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<td>3.2</td>
<td>14</td>
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</tr>
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<td></td>
<td>4.2</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RPE SCALE

6 no exertion at all
7 extremely light exertion
8
9 very light exertion
10
11 light exertion
12
13 somewhat hard exertion
14
15 hard exertion
16
17 very hard exertion
18
19 extremely hard exertion
20 maximal exertion
11.14 Cross-Validation Protocol
### Stationary Bike

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose one</td>
<td>10 minutes</td>
<td>Set the bike to one resistance value. Press armband buttons, once each.</td>
</tr>
<tr>
<td>□ 100 Watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 200 Watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observe and mark one</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Holding Handlebars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Not Holding Handlebars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Both</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choose the other one</td>
<td>10 minutes</td>
<td>Set the bike to the other resistance value. Press armband buttons, once each.</td>
</tr>
<tr>
<td>□ 100 Watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 200 Watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observe and mark one</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Holding Handlebars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Not Holding Handlebars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Both</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Elliptical

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose one LOW_INTENSITY</td>
<td>10 minutes</td>
<td>Set the elliptical to one resistance value.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choose a different one MODERATE_INTENSITY</td>
<td>10 minutes</td>
<td>Set the elliptical to another resistance value.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choose a different one STRENUOUS</td>
<td>10 minutes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Stair Stepper

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose one</td>
<td>10 minutes</td>
<td>Set the stair stepper to one resistance value.</td>
</tr>
<tr>
<td>□ LOW_INTENSITY</td>
<td></td>
<td>&quot;Start Stepping&quot;</td>
</tr>
<tr>
<td>□ MODERATE_INTENSITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ STRENUOUS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choose a different one</td>
<td>10 minutes</td>
<td>Set the stair stepper to another resistance value.</td>
</tr>
<tr>
<td>□ LOW_INTENSITY</td>
<td></td>
<td>&quot;Continue Stepping&quot;</td>
</tr>
<tr>
<td>□ MODERATE_INTENSITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ STRENUOUS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Inclined Treadmill Walking/Running

<table>
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<tr>
<th>Activity</th>
<th>Duration</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose one</td>
<td>10 minutes</td>
<td>Set the treadmill to one incline setting</td>
</tr>
<tr>
<td>□ 5% incline, 3mph</td>
<td></td>
<td>Ensure they do not hold onto handrails</td>
</tr>
<tr>
<td>□ 10% incline, 3mph</td>
<td></td>
<td>“Start Walking/running”</td>
</tr>
<tr>
<td>□ 5% incline, 5mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 3% incline, 5mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 4% incline, 5.5mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 2% incline, 5.5mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choose a different one</td>
<td>10 minutes</td>
<td>Set the treadmill to one incline setting</td>
</tr>
<tr>
<td>□ 5% incline, 3mph</td>
<td></td>
<td>Ensure they do not hold onto handrails</td>
</tr>
<tr>
<td>□ 10% incline, 3mph</td>
<td></td>
<td>&quot;Continue Walking/running&quot;</td>
</tr>
<tr>
<td>□ 5% incline, 5mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 3% incline, 5mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 4% incline, 5.5mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 2% incline, 5.5mph</td>
<td></td>
<td></td>
</tr>
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</table>
11.15 Statistical Analysis
(1) Adult and Adolescent Treadmill Equations. METs and counts

Estimates of Fixed Effects

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<th>Sig.</th>
<th>95% Confidence Interval</th>
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a. Dependent Variable: METs.

Estimates of Covariance Parameters

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a. Dependent Variable: METs.

Information Criteria

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The information criteria are displayed in smaller-is-better forms.

a. Dependent Variable: METs.
(2) Adult and Adolescent Treadmill Equations. METs and counts with body weight as a covariate.

### Estimates of Fixed Effects\(^a\)

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\(a.\) Dependent Variable: METs.

### Estimates of Covariance Parameters\(^b\)

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\(b.\) Dependent Variable: METs.

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The information criteria are displayed in smaller-is-better forms.

\(a.\) Dependent Variable: METs.
(3) Mixed model Statistics: Free Living walking only (no gym activities)

Information Criteria

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The information criteria are displayed in smaller-is-better forms.

a. Dependent Variable: OMMET.

Estimates of Fixed Effects

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a. Dependent Variable: OMMET.
(4) Forced Entry Regression Analysis for Chapter 8

### Coefficients

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a. Dependent Variable: BMIPre

### Coefficients

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a. Dependent Variable: DiastPre

### Coefficients

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a. Dependent Variable: BMIPre
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a. Dependent Variable: WaistPre

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<th>Collinearity Statistics</th>
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a. Dependent Variable: SystPre
(5) Independent sample t-tests

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(6) Sedentary bout **length** differences between weekday and weekend day

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<th>95% Confidence Interval</th>
<th>Std. Error Difference</th>
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(7) Variation in counts (per min) at each speed during the treadmill protocol (chapter 5)

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<th>ActivPAL counts (per min)</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
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