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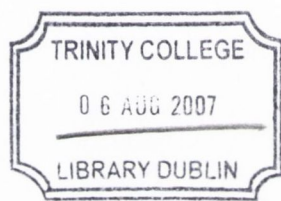
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THESIS
8188

THE INTER-RELATIONSHIP BETWEEN BODY COMPOSITION,
PHYSICAL ACTIVITY AND FITNESS IN CHILDREN

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Submitted for the degree of Doctor in Philosophy

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May 2007

Declaration

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A handwritten signature in dark ink, appearing to read 'Juliette Hussey', with a stylized, cursive script.

Juliette Hussey

8th May 2007

Summary

There is growing concern about the epidemic of childhood obesity and its associated health consequences. Contributing factors to this epidemic may be reduced levels of physical activity and increased levels of physical inactivity. Recommended guidelines for physical activity in children have increased but one could question if they are adhered to and if they are adequate. Studies, in children, investigating the relationship between body composition and physical activity have used a number of different methods to measure physical activity. In adults fitness appears to be related to a healthy body composition but this area has not been extensively addressed in children. The overall aim of this thesis was to investigate the relationship between body composition, physical activity levels and fitness in children.

The initial study was a large survey on activity levels in 7-9 year old school children in Dublin. Parents of 786 children completed a questionnaire which investigated time spent in hard and light activity, time spent sedentary, mode of transport to school and energy expenditure in regular activity. Depending on the activity recommendation used the numbers not engaging in sufficient physical activity varied from 4% to 41% in boys and 12% to 58% in girls. The energy expenditure in regular activity in boys was significantly higher than that in girls (boys: 46 Met/hr/wk versus girls: 33 MET/hr/wk, $P < 0.001$). Sixty per cent of children spent 2-3 hours per day sedentary and only 40% walked to school. However, the limitation of not assessing non-organised, intermittent activity needs to be addressed as this type of activity is natural in young children. The need to find a method of measuring overall activity in addition to intensity of activity led to the second study where the validity of a tri-axial accelerometer (the RT3) was investigated.

The RT3 is a relatively new tri-axial accelerometer which appeared to offer the possibility of objectively measuring physical activity in children. The second study investigated the validity of energy expenditure via the RT3 against the criterion of energy expenditure calculated from oxygen consumption by indirect calorimetry. The exercises, performed on a treadmill, included walking at 3 km/h, walking at 6 km/h, walking at 6 km/h on an incline of 10 degrees, and running at 9 km/h. Inactivity was also assessed with the child sitting quietly and playing a computer game. There were no significant differences between the two methods for each activity. Due to these findings the use of the RT3 accelerometer was deemed appropriate for the objective measurement of physical activity levels.

The RT3 was therefore used in a third study which aimed to determine the relationship between body composition, physical activity (including intensity of activity) and fitness in children aged 7-9.9 years. Measures of blood pressure were also examined. Data on 152 children was obtained for all measures and fitness, body composition and blood pressure was obtained in 224 children. Compared to normative data children were found to be taller, heavier and had higher waist circumferences, indicating the change in body composition that has occurred over the past 15 years. Boys were found to engage in approximately twice as much vigorous and hard activity compared to girls (mean and 95% confidence intervals 64.3, 53.2 to 75.4 minutes in boys compared to 37, 33.1 to 40.9 minutes in girls, $P < 0.001$). All but two subjects (of the 152 with activity data) were found to engage in activity recommendations. In boys there was significant difference between those defined as normal, overweight and obese in the time spent in vigorous activity ($P < 0.05$) but no such difference was found in girls. While a significant negative correlation between waist circumference and time spent in vigorous activity ($r = -0.31$, $P < 0.05$) was found in boys but not in girls this was

not significant with regression analysis ($P=0.06$ in boys). In both genders there were significant negative correlations between fitness and both BMI ($r=-0.274$, $P<0.001$) and waist circumference (boys: $r=-0.503$, $P<0.01$; girls: $r=-0.286$, $P<0.01$). Regression analysis revealed that in both genders fitness was found to be an explanatory variable for body composition ($P<0.001$ boys, $P<0.01$ girls).

The final study was carried out in children attending a weight reduction clinic in a Paediatric Hospital. Activity and inactivity levels were obtained in 40 subjects (17 boys and 23 girls) and these subjects demonstrated very high levels of inactivity and low levels of vigorous activity compared to children of normal weight.

In children aged 7-9.9 years no direct relationship between body composition and activity was found but there was a relationship between waist circumference and fitness. Physical activity levels were higher in boys than girls. This was confirmed by both subjective and objective measures. The fact that most children were meeting current recommendations yet a number were overweight suggest that recommendations need to be higher in order to achieve higher levels of fitness. The main finding in this thesis was that fitness is an explanatory variable in body composition in children. A major problem in the study of activity levels is the question of how much activity is required for health and fitness and how the different intensities of activity are determined.

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There are so many people I need to thank for their help in getting me to this stage.

To my supervisors Dr John Gormley and Professor Christopher Bell, I can never thank you enough for your encouragement, support, guidance and patience over the past few years. Being head of department at the same time as doing this research was not easy and I thank you so much for your support though this time. I would also like to thank Kathleen Bennett for all her help with the statistical analysis and her unending patience. I would particularly like to thank my aunt Dr Caroline Hussey for her proof reading and help with this work in addition to her generosity and advice over the past few years.

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Robert and Gavin you have been such an inspiration to me and the greatest gift of all. I thank you from the bottom of my heart for everything. I love you both so much.

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Submitted papers

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LIST OF ABBREVIATIONS

ACSM- American College of Sports Medicine

BMI- Body Mass Index

BP- Blood Pressure

CHD- Coronary Heart Disease

CO₂- Carbon Dioxide

CRR- Cardiorespiratory fitness

CRP- C Reactive Protein

CSA- Computer Science Application

CSO- Central Statistics Office

DED-Deprivation index- Electoral Division

DEXA- Dual- energy X-ray absorptiometry

DLW- Doubly Labelled Water

DBP- Diastolic Blood Pressure

EASO- European Association of the Study Obesity

EE- Energy Expenditure

ECG- Electrocardiogram

EYHS- European Youth Heart Study

FFM- Fat free mass

FM- Fat mass

HDL-C- High density lipoprotein-cholesterol

HR- Heart Rate

HRR- Heart Rate Reserve

ICC- Intra class correlation

IL-6- Interleukin-6

IOTF- International Obesity Task Force
 LOA- Limits of agreement
 LDL-C – Low density lipoprotein-cholesterol
 LTPA- leisure Time Physical Activity
 MAQA- Modifiable Activity Questionnaire for Adolescents
 MODY- Maturity Onset Diabetes in the Young
 MPA- Moderate Physical Activity
 MRI- Magnetic Resonance Imaging
 MST- Multi-stage Shuttle Test
 MVPA- Moderate to vigorous physical activity
 NIDDM- Non insulin dependent diabetes mellitus
 O₂ – Oxygen
 OR- Odds ratio
 PE- Physical Education
 PWC- Peak work capacity
 RR- Relative risk
 SAHRU- Small Area Health Research Unit
 SBP- Systolic Blood Pressure
 TBW- Total Body Water
 TG- Triglyceride
 TNF-alpha- Tumor Necrosis Factor
 VO_{2 max}- Maximum Oxygen Consumption
 VPA- Vigorous Physical Activity
 WHO- World Health Organisation

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CHAPTER 1: INTRODUCTION

1.1 Obesity in children

1.1.1 Preamble

The issues of increased levels of childhood obesity and the resultant health consequences are topics rarely out of the media. It appears that the problem of childhood obesity has been caused by a simple mismatch between energy consumed versus energy expended. Theoretically, therefore, the problem should be one that can be managed with appropriate public health guidelines. On deeper analysis, however, the issue may be more complicated, with the inter-relationship between body composition, activity and fitness in children requiring a more thorough investigation. There are guidelines for physical activity in children, and the activity levels recommended have increased over recent years but the adherence to guidelines by children needs examination. The evidence supporting the guidelines may need to be evaluated.

This section of the thesis examines the current incidence, the related risk factors and the health consequences of childhood obesity. The literature relevant to the relationship between body composition (and other cardiovascular risk factors) and physical activity is discussed in the following section (1.2) and the relationship between body composition (and other cardiovascular risk factors) and fitness will be considered in section 1.3. The following section in this chapter will discuss levels of physical activity and fitness in children and the factors that influence these variables. The databases used for searching the literature were Pubmed and Cinahl. Pubmed is a service from the National Library of Medicine which provides access to over 11 million MEDLINE citations back to the mid 1960's. Cinahl is a database which covers nursing and health related publications from 1982. The terms used in the search were "physical activity", "physical activity levels", "body composition", "fitness",

“aerobic capacity”, “children”, “physical activity recommendations”, “cardiovascular risk factors”, “blood pressure” and “inflammatory markers”.

The experimental work in this thesis began in 1999. However since then there has been a number of papers published which are related to this general area. Therefore, while the literature review is comprehensive, many of the studies discussed were not available at the time of the design of the studies.

In 1997 obesity was declared a global epidemic that had major health implications (World Health Organisation (WHO), 1997) and as such was described as “one of the greatest public health challenges of the 21st century”. Globally, there are more than 1 billion overweight adults, of whom 300 million are obese (WHO, 2004). In many European countries the prevalence of obesity has tripled in the last 20 years. Adult obesity is associated with higher rates of risk factors for cardiovascular disease, which include hypertension, hyperlipidemia and insulin resistance (Kress *et al.*, 2005).

It is estimated that there are 22 million children under five years worldwide who are overweight. The health implications of obesity in children include insulin resistance, hypertension, obstructive sleep apnoea, non-alcoholic steatohepatitis, orthopaedic conditions, poor self-esteem and a low health-related quality of life (Freedman *et al.*, 1999 (a); Reinehr *et al.*, 2005; Genovesi *et al.*, 2005; McMuray *et al.*, 1995; Viner *et al.*, 2005; Wing *et al.*, 2003; Rashid and Roberts, 2000; Schwimmer *et al.*, 2003; Sulit *et al.*, 2005).

1.1.2 Incidence and prevalence of obesity in children

The incidence of a disease is defined as the number of new cases occurring in a population during a specific time interval. Prevalence is defined as the number of individuals with a

certain disease at a specified time divided by the number of individuals in the population at that time (Sahai and Khursid, 1996). Prevalence does not give information about risk. A disease that is easily transmitted but with a short duration may have a low prevalence and a high incidence. Prevalence simply means the proportion of the population with the condition in question (e.g. 20% of people in the US are obese) and involves all affected individuals, regardless of when the disease was contracted

The increase in the prevalence of childhood obesity has been rapid over the last number of years, both in developed and developing countries. In countries that are industrialised it is children in lower socio-economic groups who are at greatest risk, and, in contrast in developing countries, the prevalence of obesity is higher in those from the wealthier sections (Lobstein *et al.*, 2004). Countries undergoing rapid socio-economic transition, such as Brazil and China, now face the double burden of malnutrition and obesity, with obesity seen particularly in urban areas where economic growth has been considerable (Wang *et al.*, 2002).

The most recent data compiled in Europe on obesity are from the International Obesity Task Force (IOTF) (a federal body of obesity research associations in 50 countries and regions, including the European Association for the Study of Obesity). The estimates that the IOTF has prepared for the WHO show a prevalence of overweight of one in five children in Europe. Each year, an additional 400,000 children become overweight adding to the 14 million plus already overweight, of whom 3 million are obese. Figures 1.1 and 1.2 below represent the prevalence of overweight and obesity in children in European countries.

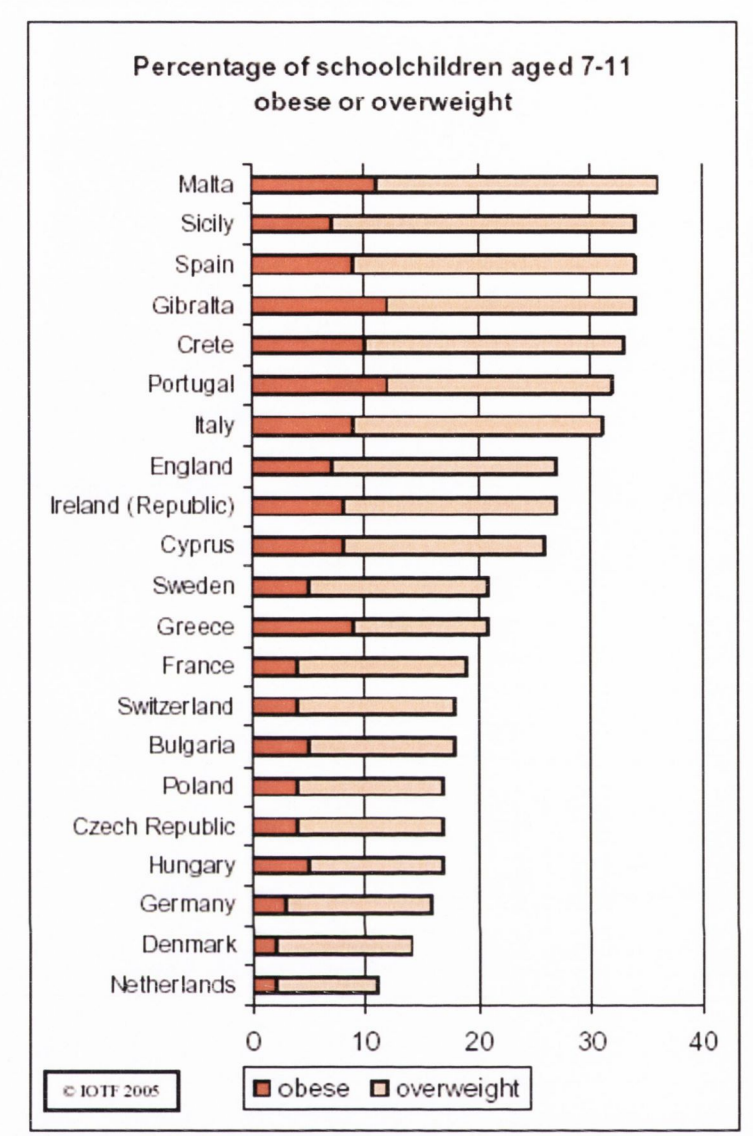


Figure 1.1: Overweight and obesity prevalence for European Countries, 7-11 year olds
(European Association for the Study of Obesity www.easoobesity.org)

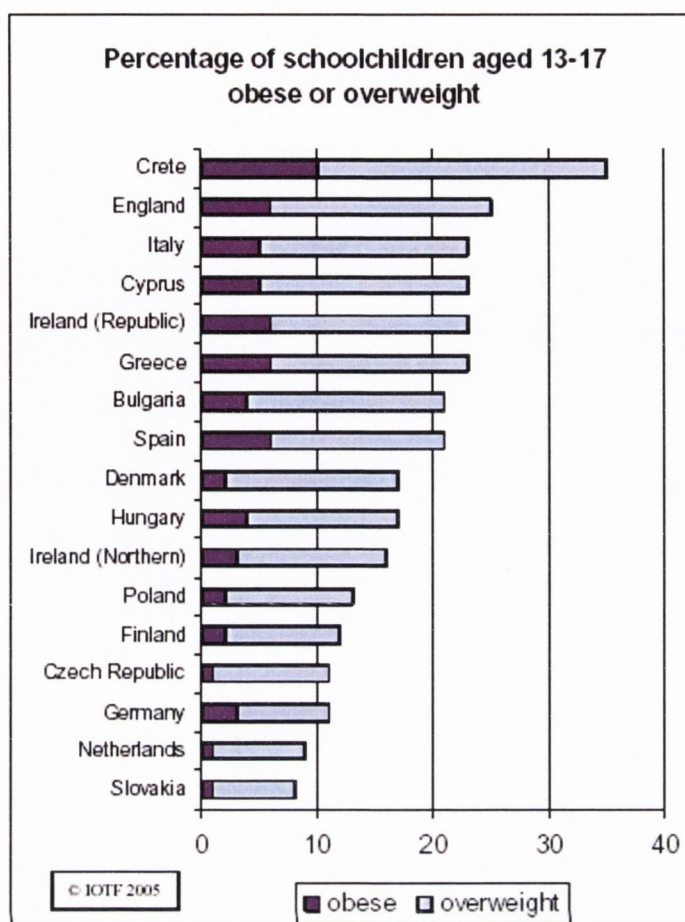


Figure 1.2: Overweight and obesity prevalence for European Countries, 13-17 year olds (European Association for the Study of Obesity www.easoobesity.org)

Increases in the numbers of children overweight and obese have been seen in recent years in many studies. Bundred *et al.* (2001) evaluated trends in weight, height and body mass index (BMI) in children under 4 years in the UK between 1989 and 1998, and found a highly significant increasing trend in the proportion of children overweight (14.7% to 23.6%, $P < 0.001$) and obese (5.4% to 9.2%, $P < 0.001$). In South Wales, Jones *et al.* (2005) examined data over the previous 16 years and compared BMI results on 46073 children aged 5 years to international cut-off points (defined by Cole *et al.*, 2000; see Chapter 2, page 86). The mean

BMI for boys in 1986 was 15.8, compared to 16.2 in 2002. In girls, in 1986, the mean BMI was 15.7 and at the end of the 16 year period it was 16.2. The proportion of boys obese at the beginning of the study was 2.5%, compared to 4.6% in 2001/02. In girls, these figures rose from 3.6% in 1986/87 to 6.9% in 2001/02. Thus, the proportion of overweight and obese children had increased significantly over the study period ($P<0.001$). In the United Kingdom, Rudolf *et al.* (2004) followed a cohort of 315 schoolchildren over 6 years from 1996 to 2001. It was found that BMI and waist circumferences increased substantially over the time (both $P<0.001$). In 1996 10% of boys and 13% of girls were overweight, and, by 2001, this had increased to 14% and 16%, respectively.

A U.K. study found that 10% of boys in England were overweight, compared to 13% in Scotland, and, in girls, these figures were 13.5% and 15%, respectively (Chinn and Rona, 2001). In the same year in Northern Ireland, Yarnell *et al.* (2001) found that 16% of boys and girls aged 13-14 years, were overweight. In Greece, higher figures were seen, where Lobstein and Frelut (2003) found 31% of children were overweight.

In addition to the increase in BMI in the past 10-20 years, there has been an increase in waist circumference (i.e. central obesity) which has exceeded the increase in BMI (McCarthy *et al.*, 2003). McCarthy *et al.* (2005) compared waist circumference and BMI between a contemporary cohort and similar aged children in the UK from 1987. A total of 1821 children aged between 2 and 5 years were measured. Mean waist circumferences in the contemporary cohort were significantly higher ($P<0.05$) than the children measured in 1987, as was BMI ($P<0.05$), but the proportional increase in waist circumference exceeded the increase in BMI. Garnett *et al.* (2005) also investigated changes in central adiposity in children aged 7-8 and 12-13 years. It was found that, between the two occasions, indices of central adiposity increased more than total adiposity (between 7-8 years and 12-13 years waist circumference z

score increased by 0.74 ± 0.92 and BMI z score increased by 0.18 ± 0.67). The agreement between classifying young subjects as overweight/obese based on total adiposity and central adiposity was compared. Waist circumference identified a greater number of subjects as overweight/obese than BMI (41.2% versus 29.3%, $P < 0.001$)

1.1.3 All-cause mortality and health consequences due to obesity

(a) All-cause mortality

The long term risks of obesity have been studied, and, in adults, body weight and mortality are related. In children, there are considerably fewer data relating obesity to mortality, due to a lack of longitudinal studies in the area. The relationship between body weight and all-cause mortality was investigated as part of the Harvard Alumni Study (Lee *et al.*, 1993). Between 1962/1966 and 1988, 19297 Harvard Alumni (mean age 46.6 years) were followed up, and data on BMI, smoking and physical activity were examined in relation to all-cause mortality. The relative risk of dying for men with a BMI < 22.5 , $22.5 \leq 23.5$, $23.5 \leq 24.5$, $24.5 \leq 26.0$, and ≥ 26.0 were 1.0 (referent for those of BMI < 22.5), 0.99 (95% CI, 0.8-1.28), 0.95 (95% CI, 0.87-1.05), 1.01 (95% CI, 0.91-1.1), and 1.18 (95% CI, 1.08-1.28), respectively. These results indicate that those who were overweight (BMI ≥ 26.0) had a higher relative risk of dying.

Hu *et al.* (2004) examined the associations of BMI and physical activity with death in 116564 women, who at baseline in 1976 were aged 30-55 years and had no evidence of cardiovascular disease or cancer. During the 24 years of follow-up, 10282 deaths occurred, of which 2370 were from cardiovascular disease, 5223 were from cancer and 2689 were from other causes. Mortality rates increased in subjects with higher BMI, even among those who never smoked (P for trend < 0.001). The relative risks of death were based on BMI and activity (activity was defined as 3.5 hours per week exercising). For lean and inactive

women, the relative risk of death was 1.55, for obese but active women it was 1.91, and for inactive and obese women it was 2.42. The authors concluded that excess weight and low levels of physical activity are strong and independent predictors of mortality. Katzmarzyk *et al.* (2003) reviewed the relationship between physical inactivity and excess adiposity and an increased risk of all-cause mortality, and they found, from the studies reviewed, that the relative risk of all-cause mortality for an elevated BMI was 1.23.

The relationship between being overweight as an adolescent and morbidity and mortality was investigated as part of the Harvard Growth Study of 1922 to 1935 (Must *et al.*, 1992). Adolescents with a BMI > 75th percentile on two occasions were defined as overweight and those with a BMI between the 25th and 50th percentile were defined as lean. Adolescent overweight was associated with an increased risk of all-cause and disease-specific mortality in men but not in women.

(b) Health consequences of obesity

As stated earlier, a number of health consequences are related to obesity in children. These include cardiovascular risk factors, such as hypertension, hyperlipidemia, impaired glucose tolerance and the insulin resistance syndrome (Freedman *et al.*, 1999, b; Reinehr *et al.*, 2005; Genovesi *et al.*, 2005; McMurray *et al.*, 1995; Viner *et al.*, 2005). Other health consequences of obesity in children are orthopaedic and respiratory problems (Sulit *et al.*, 2005) and mental health concerns (Zametkin *et al.*, 2004).

The Bogalusa Study is a longitudinal study which followed subjects from childhood for 30 years, and described the incidence and prevalence of biological and behavioural cardiovascular disease risk factors. The aim of the study was to determine the natural history of atherosclerosis, coronary artery disease and hypertension in children and adults from birth

to 40 years. As part of the Bogalusa study, it was found that more than 60% of overweight children had at least one additional cardiovascular risk factor, and overweight children were more likely to have elevated total cholesterol (2.4 times that in non-overweight), triglycerides (7.1 times that in non-overweight), low density lipoprotein cholesterol (LDL) (3 times that in non-overweight), fasting insulin (12.6 times that in non-overweight), systolic and diastolic blood pressure (4.5 and 4.1, respectively) and reduced high density lipoprotein cholesterol (HDL) (3.4 times that in non-overweight) (Freedman *et al.*, 1999, b).

An association between obesity in children and elevated blood pressure (BP) and/or elevated cholesterol has been demonstrated in a number of cross-sectional studies. Genovesi *et al.* (2005) investigated the prevalence of high BP in Italian children, aged 6-11 years, and questioned the association between elevated BP values and being overweight. The prevalence of high BP in this population of 2416 children was 4.2%, and the percentage of subjects with high BP was significantly higher in those who were overweight ($P < 0.0001$). A similar age group of children was studied by Graf *et al.* (2005), who examined anthropometric data and blood pressure in 1689 children with a mean age of 8.2 ± 1.3 years. Obesity was seen in 7.3%, and 10.4% were overweight. Resting hypertension was seen in 2.3% of the children. Increased blood pressure was associated with a higher body weight, BMI, BMI SDS score (or z score) (see Chapter 2, page 86 and Chapter 5, page 135 for description of BMI SDS score), waist and hip circumferences (all $P > 0.001$). In subjects of a slightly younger age (5-6 years), Gutin *et al.* (1990) found diastolic blood pressure to be positively related to body composition for boys ($P < 0.001$) and systolic blood pressure to be related to body composition for both genders ($P < 0.001$).

Blood pressure and total cholesterol were compared in obese and non-obese children ($n=1092$) in a case-control study (McMurray *et al.*, 1995). Obese children had higher BP

(systolic 108 ± 11 versus 104 ± 10 mmHg, $P=0.0001$ and diastolic 70 ± 9 versus 68 ± 8 mmHg, $P=0.002$), and they also had greater total cholesterol levels (4.47 ± 0.8 vs 4.11 ± 0.75 mmol/l, $P=0.001$) when compared to the non-obese. In another case-control study, Friedland *et al.* (2002) examined lipid profiles in obese and non-obese children and found that 52% of obese children had elevated serum cholesterol compared to 16% of controls.

In a purposive sample, Reinehr *et al.* (2005) investigated the presence of hypertension, low HDL, high triglycerides, total cholesterol and LDL in 1004 German children referred to obesity centres. The mean BMI SDS was 2.43. Thirty seven percent of the subjects had hypertension, 27% had increased total cholesterol, 26% had increased LDL-cholesterol, 20% had increased triglycerides and 18% had decreased HDL-cholesterol. Seventy percent of the cohort had at least one cardiovascular risk factor. BMI SDS was found to be significantly related to BP (systolic $P<0.001$, diastolic $P<0.001$), triglycerides ($P=0.007$) and negatively to HDL ($P=0.001$) but not to total or LDL-cholesterol. Thus, as with the Bogalusa study, this study found that cardiovascular risk factors were frequently present in obese children.

Obesity is associated with insulin resistance (Viner *et al.*, 2005) which is the decreased ability of insulin sensitive tissues to respond appropriately to insulin at a cellular level (Hannon *et al.*, 2005). Visceral adiposity causes higher insulin resistance than subcutaneous adiposity (Wajchenberg, 2000). Insulin resistance is the first step in the development of type-2 diabetes (Hannon *et al.*, 2005). The earlier the onset of type-2 diabetes, the greater the likelihood of the onset of associated complications, which include neuropathy, retinopathy, nephropathy and atherosclerotic cardiovascular disease, such as myocardial infarction and stroke. Childhood

type-2 diabetes was first described in the Pima Indians in 1979 (Savage *et al.*, 1979), but, more recently, cases of impaired glucose tolerance and type-2 diabetes have been described

in a small number of European children with obesity (Drake *et al.*, 2002; Wiegand *et al.*, 2004).

Zhu *et al.* (2005) compared sub-clinical atherosclerosis in children with and without obesity and found that blood lipids and carotid intima-media thickness were significantly higher in obese subjects (both $P < 0.01$). The genesis of early atheroma in children was studied by Tounian *et al.* (2001) in a case control study, and obese children were compared to controls, and were found to have significantly lower arterial compliance ($P = 0.02$) and lower distensibility ($P = 0.0001$). Arterial wall stiffness and endothelial dysfunction were demonstrated in these subjects, and the authors suggested that low plasma apolipoprotein A-I, insulin resistance and abdominal fat distribution may be the main risk factors for these arterial changes

Other physical health consequences of childhood obesity include pulmonary, orthopaedic and gastroenterological conditions (Lobstein *et al.*, 2004). The link between asthma and obesity has been studied, and, while no causal link has been demonstrated (Chinn, 2003), asthma is considered as a risk factor for obesity in children and adolescents (Gennuso *et al.*, 1998). In those with severe obesity, increased resistance to upper airway airflow may lead to snoring, hypopnoea and apnoea (Daniels, 2006).

Orthopaedic complications may arise in obese children as the tensile strength of bone and cartilage is stressed with the extra weight. Obese children are at increased risk of slipped capital epiphyses of the femur, scoliosis, tibia vara (WHO, 1998), as well as foot discomfort. Children with obesity also experience psychological problems which may be related to the child experiencing stigmatisation and low self-esteem (Strauss, 2000).

It can be seen from the studies presented that the health consequences of obesity in children are considerable and include the cardiovascular, pulmonary and musculoskeletal systems, in addition to psychological well-being.

1.1.4 Risk factors for obesity

The definition of a risk factor is presented in the section 1.2 (pages 15-16). The identification of risk factors for childhood obesity is required, in order to address the rapidly rising prevalence of childhood obesity. The simple concept of an energy imbalance, i.e. too much energy consumption versus insufficient energy expenditure through physical activity, may be the biological reason for increased body mass, but the specifics of such need further evaluation. In adults, there is evidence supporting the concept of decreased physical activity as a risk for obesity, as outlined in the studies below.

In Finland, Haapanen *et al.* (1997) found that men and women with no regular physical activity had an odds ratio of 2.59 and 2.67 for significant weight gain in comparison to those most active. A European Union study, involving 15239 adults, found that obesity and higher body weight were strongly associated with a sedentary lifestyle (Martinez-Gonzalez *et al.*, 1999). Energy expenditure during leisure time was calculated in METs, and sedentary time was measured in self-reported hours. The adjusted prevalence odds ratio for obesity was 0.52 ($P<0.001$) for the upper quintile of physical activity (>30 METs), compared to the most inactive quintile (<1.75 METs). In addition, a positive association was found between sedentary time and higher body weight, with an adjusted odds ratio of 1.61 ($P<0.001$) for those who spent more than 35 hours of leisure time sedentary compared to those who spent less than 15 hours.

A study of the 1970 British Birth Cohort (Viner and Cole, 2006) examined BMI measures at 16 years (1986) and 30 years (2000) in 4461 subjects. An increase in BMI-SDS score between 16 and 30 was predicted by 4 or more hours per day in sedentary activities ($P=0.01$), eating takeaway meals at least twice per week ($P=0.009$) and consuming at least two carbonated drinks per day ($P=0.04$). A decrease in BMI from 16 to 30 years was predicted by female sex ($P=0.01$), higher social class ($P<0.0001$), and marginally by a higher frequency of sport ($P=0.05$).

In children, the area of risk factor identification for obesity has recently been studied. In a longitudinal study in Australia, Burke *et al.* (2005) found that BMI was consistently higher in offspring who had overweight/obese fathers ($P=0.033$ for sons and $P=0.024$ for daughters) or mothers ($P=0.031$ for sons and $P=0.037$ for daughters). No association between birth weight and obesity at 18 years of age was found. In Brazil, risk factors for overweight in low income families were investigated by means of a case-control study (Silveira *et al.*, 2006). Having obese parents, or being obese as an infant, resulted in an odds ratio of 2.23 (1.15-4.35) and 3.60 (1.47-8.80), respectively, for being overweight at 14-19 years. No associations were found with dietary and activity patterns. The question of infant weight as a later risk factor for obesity was also investigated by Dennison *et al.* (2006), who measured weight in a cohort to determine if rapid weight gain in the first six months of life was associated with risk of childhood overweight and if the risk differed by ethnicity and/or breast feeding history. The rate of infant weight gain was significantly associated with being overweight at four years (odds ratio 1.4 (95% CI, 1.3-1.6)) after adjusting for birth weight, ethnicity and breast feeding). However, neither breast feeding or the timing of the introduction of complementary foods were associated with adiposity at five years in a group of 313 children (Burdette *et al.*, 2006).

This section has detailed the incidence of childhood obesity and its associated health consequences and possible risk factors. One of the main questions of this thesis is the relationship between body composition and physical activity, and the literature relevant to this question will be reviewed in section 1.2.

1.2: Physical activity and health

1.2.1 Overview of physical activity in the prevention of cardiovascular risk factors- adults

(a) Introduction

This section presents the key studies that have contributed to the evidence of the benefits of physical activity on all-cause and cardiovascular mortality and the benefit of physical activity in the prevention and management of cardiovascular risk factors. Physical activity is defined as body movement produced by the skeletal muscles and results in energy expenditure (Caspersen *et al.*, 1985). It includes exercise which is structured repetitive physical activity.

The Oxford Medical Dictionary defines a risk factor as a ‘an attribute such as a habit (e.g. cigarette smoking) or exposure to some environmental hazard, that leads the individual concerned to have a greater likelihood of developing an illness ‘ (2002). Risk factors can be modifiable or non-modifiable. Modifiable risk factors are those that are amenable to change through lifestyle, behavioural and pharmacological measures.

Many parameters in medical science have statistical associations, but not a causal relationship. Hill (1965) outlined a systematic approach for using scientific judgement to infer causation from statistical associations observed in epidemiology. Nine criteria were listed for consideration when judging if an observed association is a causal relationship. The criteria are presented below:

1. *The strength of association.* The stronger the relationship between the independent variable and the dependent variable, the less likely the relationship is due to random error. A weak association is more likely to be spurious, arising from bias, or chance.
2. *Temporality.* It is necessary for a cause to precede an effect, e.g. smoking preceded the onset of lung cancer.

3. *Consistency*. If there are a number of observations of an association, with different subjects, under different circumstances and with different measurement instruments there is an increase in the credibility of a finding. This has been seen with many studies finding an association between physical activity and cardiovascular mortality.
4. *Theoretical plausibility*. There is a rational and theoretical basis for the conclusion
5. *Coherence*. There are no plausible competing theories or rival hypotheses. The association is coherent with other knowledge.
6. *Specificity in the causes*. The effect has only one cause, i.e. if an outcome is predicted by one primary variable there is increased credibility of a causal relationship.
7. *Dose response relationship (or biological gradient)*. There should be a direct relationship between the risk factor and the status of the disease variable, e.g. a linear relationship between the amount smoked and the incidence of lung cancer.
8. *Experimental evidence*. Related experimental evidence makes a causal inference more plausible, e.g. data from animal experiments.
9. *Analogy*. A commonly accepted phenomenon in one area can be applied to another, e.g. if one drug can cause birth defects then so could another similar type of drug.

These nine criteria need to be considered when judging if an association between two factors may be causal. The following section presents the evidence for reduced physical activity as a risk factor for cardiovascular disease.

(b) Cardiovascular disease

Cardiovascular disease has been a significant health problem in Western Europe and in the US for many years and, in more recent years, has become an increasing concern in Eastern Europe and Asia (World Health Report, 2003). In 2002, just over half (16.7 million) of all deaths worldwide, due to non-communicable diseases, were the result of cardiovascular disease (World Health Report, 2003), and coronary heart disease (CHD) and stroke were the

leading causes of death in those aged over 60 years (World Health Report, 2003). In 2001, in the UK and in Ireland, 41% of all deaths were due to cardiovascular disease (British Heart Foundation, 2003; CSO, 2002). While the clinical symptoms of coronary heart disease usually do not commence until adulthood, signs of arterial damage (fatty streaks and fibrous plaques) on post mortem, have been seen in young children (Berenson *et al.*, 1998). The severity of the arterial damage has been found to be associated with the number of cardiovascular risk factors present (Berenson *et al.*, 1998).

Risk factors for CHD have been identified by a number of longitudinal epidemiological studies. One of the first studies, the Framingham study, commenced in 1948 and initially consisted of over 5000 men and women aged 30-62 years who had no evidence of CHD. The aim of the study was to examine the relationship between the incidence of CHD and certain factors over a prolonged time period. The Framingham study and other similar studies have led to the identification of multiple risk factors and permitted the natural epidemiology of CHD to be investigated, prior to commencing wide preventative measures.

Cardiovascular disease risk factors that have been identified include obesity, smoking, hypertension, hypercholesteremia, insulin resistance, inflammatory markers, low fitness and inactivity. Inactivity, in addition to being an independent risk factor for cardiovascular disease, is also associated with other cardiovascular risk factors. Therefore, it is clear that the issue of specificity is not seen in terms of a single risk factor for cardiovascular disease. There is considerable evidence supporting the risks of inactivity on all-cause and cardiovascular mortality in adults. In children, there is less evidence, probably due to the lack of longitudinal studies. There is, however, evidence supporting the beneficial effect of physical activity on a number of cardiovascular parameters in the young.

(c) Physical activity, all-cause and cardiovascular mortality

This section presents the evidence for the beneficial effects of physical activity on all-cause mortality and cardiovascular mortality. The subsequent section will present the evidence for the beneficial effects of physical activity on cardiovascular risk factors. The relative risk is the probability of a specific occurrence within a stated period of time (Campbell and Machin, 1999) and is one of the attributes of a cohort study. It measures the extent to which an individual with a risk factor is likely to get a disease compared to an individual without the risk factor (Vetter and Mathews, 1999). In a case-control study, the odds ratio for exposure and disease is calculated. The odds ratio is calculated by dividing the odds of exposure in the diseased group by the odds of exposure in the non-diseased group (Jekel *et al.*, 2001).

Much of the research investigating activity and all-cause mortality has focused on cardiovascular mortality. One of the first researchers to demonstrate the link between activity and cardiovascular disease was Sir Jeremy Morris who, in 1966, found that bus conductors who spent much of their day walking up and down the stairs of double decker buses had a lower risk of coronary heart disease (CHD) than the bus drivers who spent most of their working day sitting (Morris *et al.*, 1966).

Another notable study investigating the relationship between physical activity and all-cause mortality was the Harvard Alumni Health Study, where activity levels in 16396 men aged 35-74 years, who had been students in Harvard between 1916 and 1950, were investigated. Activity levels were assessed in 1962 and 1966, and, at the time of follow-up in 1978, 1413 subjects had died. An inverse dose-response relationship between physical activity and all-cause mortality was found. The death rates in subjects expending at least 2000 kcal/week were 25-33% lower than those expending less than this amount (Paffenbarger *et al.*, 1986).

Haapanen-Niemi *et al.* (2000) investigated the independent associations and the interactions of BMI and leisure time physical activity (LTPA) with the risk of mortality, by means of a prospective 16 year study in Finland on 1090 men and 1222 women, aged 35-63 years. These findings demonstrated a large difference between the genders in terms of mortality and lack of vigorous activity. It was found that, compared with the most active subjects, men and women with no weekly vigorous activity had relative risks of 1.61 (95% CI, 0.98-2.64) and 4.68 (95% CI, 1.41-15.57), respectively, for cardiovascular disease mortality.

In another large study, Bucksch (2005) examined the effect of leisure time physical activity on all-cause mortality in 7187 German adults (3742 men and 3445 women) aged 30-69 years. The volume of moderate intensity activity was compared to sedentary activity, and a protective dose response was demonstrated (P for trend <0.001). Physical activity of moderate intensity for 2.5 hours per week decreased the relative risk of overall mortality to 0.65 (95% CI, 0.51-0.82) and 0.90 (95% CI, 0.77-1.01) in women and men, respectively.

The association between physical activity and BMI and the combined effect of these two risk factors on cardiovascular disease mortality was examined by Hu *et al.* (2005) in 47212 subjects aged 25-64 years. Physically active subjects had significantly lower (P<0.001) age-adjusted mortality from cardiovascular disease or cancer and all-cause mortality, compared to sedentary subjects. Obese subjects (BMI>30) had significantly higher cardiovascular and total mortality than normal weight subjects (P<0.001). The level of BMI had an inverse association with cancer mortality in men (P<0.001) and an almost significant association in women (P<0.06). In men, 5.5% of all deaths, and in women 7.7% of all deaths, were attributed to obesity.

In those with established coronary heart disease, exercise-based cardiac rehabilitation is effective in reducing mortality (Jolliffe *et al.*, 2001). This Cochrane Systematic Review on exercise-based cardiac rehabilitation found that the pooled effect estimate for total mortality for the exercise-only intervention was a 27% reduction in all-cause mortality (Odds Ratio (OR) 0.73, (95% CI, 0.54 - 0.98)).

1.2.2 Physical activity and relationship to other cardiovascular risk factors

Regular physical activity is associated with both the prevention and treatment of cardiovascular risk factors and plays a vital role in the prevention of chronic diseases including cardiovascular disease (Lee *et al.*, 2000; Mohan *et al.*, 2005). Physical activity can decrease the risk of the metabolic syndrome (Bertrais *et al.*, 2005) and can decrease the risk of diabetes in those with impaired glucose tolerance (Pan *et al.*, 1997; Tuomilehto *et al.*, 2001; Knowler *et al.*, 2002). Other cardiovascular risk factors, such as hypertension and hypercholesteremia, are improved with regular physical activity (Halbert *et al.*, 1997; Engstrom *et al.*, 1999; Hayashi *et al.*, 1999; Dickenson *et al.*, 2006). At present, the evidence for the effects of physical activity on morbidity and mortality in children is not available. This paucity of evidence may be in part due to a lack of studies that have reached a conclusion, or studies that have not been of sufficient length to examine such relationships. There is a need for multiple longitudinal studies to assess secular trends in activity in children.

Currently there are a number of population studies investigating the prevalence of cardiovascular disease risk factors in children and adolescents, and these include The Bogalusa Heart Study, The Amsterdam Growth and Health Longitudinal Study, The Northern Ireland Young Hearts Project, The Cardiovascular Risk in Young Finns Study and The European Youth Heart Study.

The Bogalusa Heart Study has examined the natural history of cardiovascular disease in the population of Bogalusa. Bogalusa is a semi rural community consisting of 22000 people (64% white and 36% black) in Louisiana. Demographic data, health history, body composition, blood pressure, serum lipid, lipoproteins, and data on nutritional factors are collected at regular intervals. The Amsterdam Growth and Health Longitudinal Study is an observational study which commenced in 1977 with a group of 450 children with a mean age of 13.1 ± 0.8 years. The goal of the study was to describe growth and lifestyle and the longitudinal relationships between biological parameters and lifestyle behaviours. Another European study which commenced around the same time is the Cardiovascular Risk in Young Finns Study, which is an ongoing investigation of atherosclerotic risk factors in Finnish children and adolescents. The first survey commenced in 1980 and the original cohort included 4320 subjects aged 3, 6, 9, 12, 15 and 18 years who were randomly picked from the national register (Raitakari *et al.*, 2003).

The Northern Ireland Young Hearts Study commenced in 1989-1990 with the aim of evaluating the presence of the major modifiable coronary risk factors in the adolescent population in Northern Ireland. The European Youth Heart Study commenced in 2000 and examines 1000 children aged 9 and 15 years in four European countries (in four distinct regions). It is school-based, and the principal cardiovascular risk factors studied are total cholesterol, high density lipoprotein cholesterol, low density lipoprotein cholesterol, triglycerides, insulin, glucose, fitness, birth-weight, fatness and distribution of body fat and lifestyle behaviours (Andersen *et al.*, 2006; Brage *et al.*, 2004; Riddoch *et al.*, 2004)

Results from these studies are discussed in this section, but the long-term findings of the studies, in terms of mortality, will take many more years. As morbidity and mortality end-

points have not yet been found to be related to physical activity in children, this section will examine how physical activity is associated with risk factors for cardiovascular disease. Many of the studies discussed in the following sections have investigated the relationship between activity and/or fitness levels and a number cardiovascular risk factors, and, therefore, it is often difficult to separate out the individual relationships. In order to avoid too much repetition, in some of the following subsection the parameters discussed may relate to factors other than that in the subheading.

In children, blood pressure values are compared to percentiles for age, gender and height, and normal blood pressure is defined as systolic and diastolic blood pressure less than the 90th percentile of these values. Hypertension is defined as average systolic or diastolic blood pressure greater than or equal to the 95th percentile for age, gender and height on three separate occasions (National High Blood Pressure Education Programme Co-ordinating Committee in 1995: Update on the 1987 task force report on high blood pressure).

The following studies examined the relationship between activity and blood pressure. In 1997 Boreham *et al.* investigated the relationship between sports participation and blood pressure in 1015 adolescents aged 12 and 15 years and found that, in 15 year old males, sports participation was beneficially associated with systolic blood pressure ($P<0.05$), but the relationship was not seen in girls. In Italy, Panico *et al.* (1987) investigated the relationship between physical activity and blood pressure in a study which involved 1341 Italian children between 7-14 years. Systolic blood pressure was found to be independently related to the level of habitual physical activity ($P<0.05$). However, physical activity as defined in this study was measured by the recovery index of the resting pulse with the Harvard – Modified Step test, which is not a measure of physical activity but rather an indicator of fitness.

The association between physical activity and measures of insulin sensitivity was investigated in 95 overweight Hispanic children aged 8-13 years (Ball *et al.*, 2004). Physical activity, as measured by a questionnaire) was not found to be related to insulin sensitivity. However, the main limitation of the study was that activity was measured by questionnaire in a relatively limited number of subjects. In contrast to these findings Schmitz *et al.* (2002) examined the association between insulin sensitivity and physical activity (measured by questionnaire) in 357 non-diabetic children aged 10-16 years and found leisure time physical activity to be correlated with lower fasting insulin ($P=0.03$) and greater insulin sensitivity ($P=0.001$). These relationships were independent of age and race.

As part of the Cardiovascular Risk in Young Finns Study, Raitakari *et al.* (1994) investigated serum insulin and triglyceride concentrations in active and non-active subjects aged 15-24 years. It was found that both were significantly lower in active males compared to those sedentary ($P<0.04$ for triglyceride and $P<0.03$ for insulin). Active male subjects also had a more beneficial high density lipoprotein / total cholesterol ratio (HDL/TC) ($P=0.03$). The differences were not seen in females, where only triglyceride concentration was associated with activity.

In younger subjects, Suter and Hawes (1993) examined the relationship between physical activity, body fat and blood lipid profiles and found an association, independent of gender, between a high level of physical activity and a favourable lipid profile in children aged 10-15 years. Physical activity was measured by means of a questionnaire using a 7 day recall. In boys, a high level of physical activity was related to higher concentrations of high density lipoprotein cholesterol (HDL) ($r=0.37$, $P<0.05$), as well as to lower concentrations of very low density lipoprotein cholesterol (VLDL), total triglycerides and HDL/TC ($r=-0.42$, $r=0.40$,

both $P < 0.01$ and $r = 0.37$, $P < 0.05$). In girls, physical activity was positively related to HDL ($P < 0.05$).

The relationship between habitual physical activity and flow-mediated dilation of the brachial artery in 47 children aged between 5-10 years was examined by Abbott *et al.* in 2002. Physical activity was measured by a validated stable isotope method over ten days and was compared with the ratio of total energy expenditure to resting metabolic rate. Total energy expenditure was determined using the doubly labelled water technique (for details of the method see Chapter 2, page 78). Habitual physical activity was found to be significantly correlated with flow mediated dilation ($r = 0.39$, $P = 0.007$). This study, where the gold standard measure of physical activity was used, lends strength to the argument that physical activity in childhood is important in preventing future disease, despite a small sample being studied.

Many studies have examined the relationship of physical activity to a number of cardiovascular risk factors. Ribeiro *et al.* (2004, b) studied physical activity and clustering of biological risk factors in 1461 Portuguese children aged between 8 and 15 years. More than 50% of the sample had at least one biological risk factor. The results demonstrated that those with higher levels of physical activity (as measured by questionnaire) had a lower number of biological cardiovascular risk factors. The odds ratio of having one risk factor in males in the lowest quartile of physical activity was 1.6 (0.8-2.7) compared to 1.3 (0.7-2.4) in males in the middle quartiles. In females the odds ratio of having one risk factor in those in the lowest quartile of physical activity was similar to girls in the middle quartiles, but for girls the odds ratio of having two or three risk factors was 1.8 (0.8-3.9) in the lowest quartile, compared to 1.0 (0.4-2.0) in the middle quartiles.

In Greece, Bouziotas *et al.* (2004) investigated the association between CHD risk factors (HDL, LDL, HDL/TC, triglycerides, blood pressure) and lifestyle parameters (fitness as measured by the 20-MST, fatness, fat intake and physical activity as measured by a questionnaire) in 210 twelve-year old children. A significant association between HDL and physical activity ($P<0.001$) was found, as was a negative relationship between systolic blood pressure and physical activity level ($P<0.001$).

The metabolic syndrome incorporates the characteristics of obesity, low glucose tolerance, hyperinsulinemia, hyperlipidemia and hypertension (Brage *et al.*, 2004). As part of the European Youth Heart Study Brage *et al.* (2004) examined the relationship between the metabolic syndrome and objectively measured physical activity in 589 children (9.6 ± 0.44 years). Activity was measured by a uni-axial accelerometer, and cardiovascular measures included blood pressure, degree of adiposity (sum of four skin-folds), insulin, glucose, triglycerides, and high density lipoprotein cholesterol. These outcome variables were statistically normalised and expressed as the number of SDs from the mean (z score). Metabolic risk, as calculated as the mean of the z scores, was inversely related to physical activity ($P=0.008$). Physical activity was inversely associated with insulin ($P=0.018$) and borderline with triglycerides ($P=0.052$), but there was no association of physical activity with measures of glucose, cholesterol, systolic, diastolic blood pressure (SBP, DBP) or skin-fold thickness.

Most of the studies above used questionnaires to measure physical activity other than that by Abbott *et al.* (2002) and Brage *et al.* (2004). In studies using questionnaires it is not possible to investigate a dose response due to the type of data obtained (i.e. ordinal). However, despite the lack of data on the specific volume of activity required for health benefits in children, the American Heart Association has produced a position statement based on the

evidence of physical activity on cardiovascular risk factors. The American Heart Association Scientific Statement on Cardiovascular Health in Childhood (Williams *et al.*, 2002) stated that the health benefits associated with a physically active lifestyle in childhood include weight control, lower blood pressure, increased psychological well being and an increased predisposition to being active as an adult. A Statement from the Atherosclerosis, Hypertension, and Obesity in the Young Committee and the Diabetes Committee of the American Heart Association advises that, on the basis of current knowledge, and based on findings from adult studies, it is recommended that lifestyle modification and weight control in children could reduce the risk of developing insulin resistance, type-2 diabetes and cardiovascular disease (Steinberger and Daniels, 2003).

1.2.3 Physical activity guidelines for children

Prior to discussing the literature on body composition and physical activity, the recommendations for physical activity in children will be presented. Activity guidelines have changed over the past number of years. Physical activity guidelines for children were first presented by the American College of Sports Medicine (ACSM) in 1988 (ACSM, 1988). The guidelines were based on those of adults, and the recommendation was that children should achieve 20-30 minutes of vigorous activity per day. The general ACSM guidelines for physical activity are that adults should accumulate at least 30 minutes of moderate intensity activity on most, and preferably all, days of the week (ACSM, 1990). In 1994 the International Consensus Conference on Physical Activity Guidelines for Adolescents recommended that “all adolescents are physically active daily, or nearly every day, as part of play, games, sports, work, transportation, recreation, physical education, or planned exercise, in the context of family, school, and community activities” and that “adolescents engage in three or more sessions per week of activities that last 20 minutes or more at a time and that require moderate to vigorous levels of exertion” (Sallis and Patrick, 1994).

More recently in the United States, an expert panel was set up by the Divisions of Nutrition and Physical Activity and Adolescent and School Health of the Centers for Disease Control and Prevention, to review and evaluate the evidence on the influence of physical activity on several health and behavioural outcomes in children aged 6-18 years, and to develop evidence-based recommendations (Strong *et al.*, 2005). A total of 850 articles were reviewed, and the areas included adiposity, cardiovascular health, asthma, mental health, injury associated with physical activity and musculoskeletal health. Most of the intervention studies reviewed included supervised programmes of 30-45 minutes of moderate to vigorous activity on 3-5 days per week. The panel recommended that “school-aged youth should participate in 60 minutes or more of moderate to vigorous physical activity that is developmentally appropriate, enjoyable, and involves a variety of activities.”

1.2.4 Body composition and physical activity

An extensive search of the literature was carried out to evaluate the current evidence on the relationship between body composition and physical activity. In reviewing the evidence to date, the papers will be classified by the method used for measuring physical activity. The methods used in the measurement of physical activity were questionnaires, observation, heart rate monitoring and motion sensors. Details of the different methods of measuring physical activity are given in Chapter 2 (pages 78-84). Generally, the studies using more objective measures have been published in recent years due to the more sophisticated technology available. These newer methods have also permitted a dose-response to be examined. The measurement of body composition in these studies has generally been by skin-folds and BMI. The measure of waist circumference has rarely been used. Very few studies have included more than 100 subjects.

(a) Studies using questionnaires to measure the relationship between body composition and physical activity

The majority of studies have used questionnaires as the method of measuring physical activity. In these questionnaire-based studies, body composition has been examined using skin-folds (the majority), underwater weighing, BMI and, in one study, waist circumference. It is difficult to examine a linear association between body composition and physical activity when activity is measured by questionnaire, as a dose of physical activity cannot be ascertained. Due to this limitation, the findings from the studies that have used questionnaires will be grouped in terms of a positive or negative relationship, but the magnitude of the association will not be elaborated on due to this difficulty in obtaining interval level data from questionnaires. While the hours of sporting activity can be determined, the intensity of activity cannot be obtained.

A significant negative relationship between body composition and physical activity was found in 16 cross-sectional or case - control studies (Bell, 1997; Deheeger *et al.*, 1997; Fu *et al.*, 1995; Johnson *et al.*, 1956; Klein-Platat *et al.*, 2005; Klesseges *et al.*, 1990; McMurray *et al.*, 1995; Maffei *et al.*, 1998; Moussa *et al.*, 1994; Muecke *et al.*, 1992; Obarzanek *et al.*, 1994; Pate *et al.*, 1990; Raudsepp and Jurimae, 1997; Sallis *et al.*, 1988; Saris *et al.*, 1980; Taylor and Baranowski, 1991), and, in a smaller number, a negative relationship between body composition and physical activity was seen in boys, but not in girls, when the genders were considered separately (Deforche *et al.*, 2003; Guillaume *et al.*, 1997; Tell and Vellar, 1988; Guerra *et al.*, 2006) or where only boys were studied (Ara *et al.*, 2004). Two studies found no relationship between body composition and physical activity in children (Boreham *et al.*, 1997; Ribero *et al.*, 2003), and, in one study, a positive relationship between body composition and physical activity was seen (Edmunds *et al.*, 1998).

Overall, the association between body composition and physical activity in these cross-sectional studies appears to be a negative one, but there are a number of limitations to these studies. Few had large numbers of subjects and the inability to capture spontaneous activity and the volume of regular activity influences the interpretation of these results.

Questionnaires and self-report have also been used to investigate the association between indicators of body fat and inactivity. Children watching more than 4 hours television per day were found to have greater body fat ($P < 0.001$) than those who watched less than 2 hours per day (Anderson *et al.*, 1998). Time spent playing video games was found to be related to body weight ($P < 0.05$) in a cohort of 2831 children aged 1-12 years (Vanderwater *et al.*, 2004), where children of higher weight spent more time in sedentary activities than those who were lighter ($P < 0.05$).

Three longitudinal studies (Berkey *et al.*, 2000; Kemper *et al.*, 1999; Ara *et al.*, 2006) have examined the relationship between body composition and physical activity. The change that occurred in activity and BMI over one year was investigated by Berkey *et al.* (2000) in 887 boys and girls aged 10-15 years. An increase in physical activity over the year was associated with a decreasing relative BMI in girls of -0.06 kg/m^2 per hour in daily activity, (95% CI, -0.11 to -0.01) and in boys who were overweight of -0.22 kg/m^2 per hour in daily activity, (95% CI, 0.033 to -0.10). An increase in inactivity (time in sedentary activities, e.g. TV/video) was associated with an increase in BMI in girls of $+0.05 \text{ kg/m}^2$ (95% CI, 0.2-0.8).

The change in body composition in relation to physical activity over a longer period of time was examined as part of The Amsterdam Growth and Health Longitudinal Study (Kemper *et al.*, 1999). High physical activity levels were related to a lower fat mass ($P < 0.01$), with no significant difference between the genders in physical activity level. A longitudinal study of

3.3 years in a small number of boys (n=42) found BMI increased with growth more in those active for at least 3 hours per week, compared to those non-active ($P<0.05$), but fat mass accumulation with growth was lower in those who were active ($P<0.05$) (Ara *et al.*, 2006). While this study had a small number of subjects, the issue of using BMI only in terms of body composition could be questioned, as increases in BMI can be due to both increases in fat and/or muscle mass.

One longitudinal study examined changes in body composition with inactivity in 1000 subjects (Hancox *et al.*, 2004). The hours spent TV watching were associated with higher BMI ($P=0.003$). Measuring hours spent in inactivity may be more accurate than measuring activity by questionnaires. It would appear from the studies to date that inactivity is positively associated with body fat in both genders, but, from the methods used, a direct response cannot be obtained

(b) Studies using observation methods to measure the relationship between body composition and physical activity

Physical activity was measured by observation in a small number of studies (Klesges *et al.*, 1984; Corbin and Fletcher, 1968; DuRant *et al.*, 1993; Li *et al.*, 1995; Taylor and Baranowski, 1991) which used a number of different methods to measure body composition (skin-folds, waist hip ratio, relative weight and DEXA (dual-energy X-ray absorptiometry)). In all studies, a negative relationship with body composition was found. However, as with questionnaires, it is not possible to quantify the relationship. Due to the labour associated with observation studies, the number of subjects studied was low, with the study by Taylor and Baranowski (1991) having the largest with 186 subjects. Where numbers are very low, the question of how representative the sample is must be asked.

(c) Studies using heart rate monitoring to measure the relationship between body composition and physical activity

Heart rate monitoring is a quantitative method of measuring physical activity and has been used to investigate the relationship with body composition, generally measured by skin-folds and/or BMI, in children (Al-Hazza *et al.*, 1994; Maffei *et al.*, 1997; Rowlands *et al.*, 1999). In measuring body composition, standardised scores were not calculated. Generally, the findings of these studies demonstrated a negative relationship. Maffei *et al* (1997) showed a positive relationship between adiposity, as measured by % fat mass, and time spent sedentary in 9 year old boys. This is another aspect of the relationship of activity/inactivity with body composition. It is difficult to quantify activity accurately from measurements of heart rate (HR), due to differences in individual fitness levels and other confounding factors which can elevate heart rate (see Chapter 2, pages 80-81), and the findings must be considered with due regard for such issues. If individual fitness assessments are not performed, then it appears that fitter children may be doing less activity for a given workload. On further analysis of the studies using HR monitoring, most used absolute thresholds of heart rate to determine specific intensities of activity (Armstrong *et al.*, 1991; Al-Hazza *et al.*, 1994; Rowlands *et al.*, 1999), rather than basing the threshold on each individual's fitness (Maffei *et al.*, 1996).

(d) Studies using motion sensors to measure the relationship between body composition and physical activity

An increasing number of studies use pedometers or accelerometers to measure physical activity in children (Almeida and Fox, 1998; Edmunds *et al.*, 1998; Klesges *et al.*, 1990; Tudor-Locke *et al.*, 2004; Ekelund *et al.*, 2004; Raustorp *et al.*, 2004; Rowlands *et al.*, 1999; Trost *et al.*, 2003; Abbott and Davies, 2004; Andersen *et al.*, 2006; Ruiz *et al.*, 2006;

Thompson *et al.*, 2005). A number of these studies have arisen out of the *European Youth Heart Study* (see page 20). The majority of these papers have been published in the last two years and were therefore not available at the time of the design of the studies in this thesis. However these studies have produced results that now need to be considered when reviewing the data in this area. A negative relationship between body composition and physical activity was found in the majority of studies but the specifics of the relationships varied and the details will be described below.

No correlation was found between weight and activity levels in the studies by Raustrop *et al.* (2004) and Thompson *et al.* (2005). In the study by Raustrop activity levels were examined in 871 children with pedometers (see Chapter 2, page 81 for details). Pedometers are relatively inexpensive but only steps counts are achievable, and therefore they have limitations in measuring overall activity. In the study by Thompson *et al.* (2005), physical activity was measured for 7 consecutive days with uni-axial accelerometers in 1653 students aged 8-16 years. No relationship between at least moderate intensity activity and BMI was found and no significant differences in the average time spent in moderate or more intense activities was seen between those of normal weight, at risk of overweight and overweight.

Tudor-Locke *et al.* (2004) performed a secondary analysis of an existing data set of pedometer assessed physical activity and BMI to establish gender standards for steps per day related to international BMI cut off points for normal weight and overweight/obesity in 1954 children aged 6-12 years. For normal weight the required number of steps for 6-12 year old children were 12,000 per day for girls and 15,000 per day for boys. The authors of the study in question state that these figures would equate to approximately 120 minutes of activity per

day for girls and 150 minutes of activity per day for boys. The study therefore suggests a quantity of activity in excess of current recommendations.

The suggestion that physical activity levels should be higher than the current international guidelines of at least 1 hour per day of at least moderate intensity to prevent clustering of cardiovascular disease risk factors is also supported by Anderson *et al.* (2006). As part of the EYHS an investigation between the associations of objectively measured physical activity with systolic blood pressure, triglyceride, total cholesterol/HDL ratio, insulin resistance, sum of four skin-folds and aerobic fitness was performed. Subjects were categorised into quintiles of physical activity and those in the lowest three quintiles had a significant raised risk in all measured risk factors. This cross-sectional study of over 1700 randomly selected 9 and 15 year olds found that the odds ratio for having clustered risk for ascending quintiles of physical activity (measured by accelerometry in counts per minute) was 3.29 (1.96-5.32), 3.13 (1.87-5.25), 2.51 (1.47-4.26) and 2.03 (1.18-3.50) respectively when compared to the most active quintile. The mean time spent above 2000 counts per minute (which represents walking at 4km/h i.e. moderate intensity) in the highest quintile was 167 minutes and in the fourth quintile it was 116 minutes for the 9 year old children. The results of a study by Ekelund *et al.* (2004) adds further support to the suggestion that physical activity guidelines need to be increased. In this latter study children who were physically active for more than 2 hours per day were significantly ($P=0.02$) leaner than those who accumulated less than 1 hour per day.

Rowlands *et al.* (1999) studied the relationship between activity levels, fitness and body fat in 34 children aged 8-10 years. Activity was measured over a 6 day period using an accelerometer (Tritrac) and a pedometer. Activity was found to be correlated negatively to percentage of body fat ($P<0.05$) as measured by skin-folds. When the genders were

separated the relationships between activity and body fat were not significant but the number in each group was small (n=17 each).

The use of some motion sensors e.g. accelerometers permit the intensity of movement to be investigated. The impact of vigorous activity on body composition has been studied more recently with the introduction of such technology. The question of the impact of the type of activity on body composition will be addressed in Study three. At the design phase of study three there were no papers found that had addressed this issue but since 2003 a number of papers have been published. The question was original at the time of study and the importance of the area is supported by the fact that others have also studied the relationship.

The relationship between intensity of physical activity and body composition in children aged 5-10.5 years (n=47) was examined by Abbott and Davies (2004) and activity was defined by minutes spent in moderate, vigorous and hard intensity activity using the Tritrac-R3D. Body fat and BMI were significantly inversely related to physical activity level ($P=0.002$, $P=0.001$). The times spent in vigorous and hard activity were significantly correlated to percentage body fat ($P=0.004$, $P=0.014$) but not BMI. Moderate intensity activity was not found to correlate with measures of body composition. This study would appear to be the first study to suggest that the relationship between activity and body composition is not simple as it is influenced by the intensity of activity. The use of more sophisticated measures such as the Tritrac permits a greater sensitivity of measurement of intensity when compared to self-report and have facilitated investigations studying intensity of activity.

Trost *et al.* (2003) studied a sample of 245 preschool children (aged 3-5 years) and compared physical activity patterns in overweight and non overweight children using both an observation system and a uni-axial accelerometer. The following activity measures (as

measured by accelerometry); mean activity rating, percentage of time spent in moderate to vigorous physical activity, total counts per hour, the number of moderate to vigorous physical activity intervals per hour and the number of vigorous physical activity intervals per hour were all significantly greater in the non-overweight boys than the overweight boys (all $P < 0.05$). In girls there were no significant differences in any of the activity variables between those overweight and non-overweight.

As part of the EYHS Ekelund *et al.* (2004) studied the association between the volume of physical activity (measured objectively with accelerometry) with indicators of body fatness (measured by skin-folds and BMI). It was found that time spent in moderate and vigorous activity ($P = 0.032$) and time in vigorous activity ($P = 0.015$) were significantly and independently associated with body fat. Children who accumulated < 1 hr of moderate physical activity per day were significantly fatter than those who accumulated > 2 hours per day ($P = 0.02$).

The association of intensity of activity in addition to total physical activity with body composition was examined by Ruiz *et al.* (2006) as part of the EYHS of a cross-sectional study of 780 children aged 9-10 years from Sweden and Estonia. Body composition was measured by the sum of 5 skin-folds and it was found that lower body fat was significantly associated with higher levels of vigorous physical activity but not with total or moderate physical activity ($P < 0.001$).

(e) Studies using other objective measures to measure the relationship between body composition and physical activity

Rush *et al.* (2003) compared body fatness and components of energy expenditure in 79 children comprising 3 ethnic groups: Maori, Pacific Island and European. Energy expenditure was measured by doubly labelled water. As in some of the other studies described above, physical activity was found to be inversely correlated with body fat in boys ($r=-0.43$, $P=0.006$) but was not significantly associated in girls.

An all female sample of 24 girls aged 7-10 years was examined by Treuth *et al.* in 1998, and energy expenditure and fitness in those overweight were compared to those of normal weight (based on percentile of BMI, with those $>95^{\text{th}}$ percentile defined as overweight). There was no difference in physical activity energy expenditure between the two groups, but the overweight subjects had significantly higher resting energy expenditure ($P<0.001$), as measured by respiration calorimetry and doubly labelled water.

The studies described above have measured body composition by skin-folds and BMI. While most of the studies included children within a narrow age band, a criticism could be that, in most, the body composition measures were not expressed as standard deviation from normal scores. The only paper to do so was that by Ruiz *et al.* (2006). Without the use of standardised measures, it is difficult to separate normal changes in body composition due to age and growth from the possible impact of physical activity.

It appears from the studies discussed above that physical activity has greater impact on body composition in boys than in girls. The dimension of physical activity that protects against obesity is unknown. When body fat, rather than just BMI, was measured there also appears to be a relationship with activity levels. Many of the above studies have incorporated a wide

spread of ages of children in the samples studied. The ages ranged from those as young as 3-5 up to 15-16 years, and where these are combined it is difficult to determine the activity levels of the specific age bands. The evidence for a relationship is strong when several studies, performed at different times, in different places and with different subjects, all arrive at the same conclusion, and it appears from the data to date that physical activity does have an impact on body composition, but the volume and intensity of activity necessary to impact on body composition has not been established.

While the increase in obesity in children is often believed due to a decline in physical activity the relationships between physical activity and body composition needs further investigation. There is a lack of consistency in terms of the methods used to measure both activity and body composition. Most studies that have used objective measures have been of cross-sectional design and therefore cause and effect cannot be established. Very few studies have investigated the associations between intensities of activity and body composition and this is possibly due to the lack of measures available to do this until recently. The lack of standardised measures of BMI have made the interpretation of findings difficult and have not permitted the comparison of studies. BMI is a measure of both fat and fat free mass, which cannot be distinguished and therefore children who engage in regular vigorous activity may have high body mass due to muscle. It may be preferable to use measures of central fat such as waist circumference to determine body composition. At the time of the design of Study 3 there appeared to be a relationship between physical activity (based on questionnaire data) and body composition in children but the specifics of the relationship were unknown and only one study had examined intensity of activity and body composition and this was only in 34 subjects. One of the main objectives of Study 3 was to examine the relationship between time spent in different intensities of activity and body composition. Body composition was measured by both BMI and waist circumference.

1.3 Physical fitness and health

1.3.1 Introduction

The previous section presented the evidence for the benefits of physical activity on cardiovascular disease and specifically on body composition. Another aspect related to physical activity but yet a distinct characteristic is the attribute of physical fitness. Low cardiovascular fitness is another important health concern that needs to be considered in the study of body composition and physical activity (Lee *et al.*, 1999).

This section will present the evidence of the relationship between body composition and fitness and between other cardiovascular risk factors and fitness.

1.3.2 Definition and measurement of fitness

Physical fitness may be defined in terms of aerobic capacity, musculoskeletal flexibility and muscular strength and endurance. This section focuses on aerobic capacity and this term will be used interchangeably with the term physical fitness. The “gold standard” criterion of aerobic capacity is maximal oxygen uptake ($\text{VO}_{2\text{max}}$). $\text{VO}_{2\text{max}}$ is usually expressed in one of 2 ways: in absolute terms as litres per minute (litres/min) or relative to an individual’s body mass in millilitres per kilogram per minute (ml/kg/min). $\text{VO}_{2\text{max}}$ depends on the strength of the heart, the blood volume, the blood oxygen carrying capacity and the muscle oxygen extraction (McArdle *et al.*, 1996). There are a number of factors which affect $\text{VO}_{2\text{max}}$ including genetic make-up, age and gender. In addition, the amount and intensity of activity and exercise that are regularly performed can affect $\text{VO}_{2\text{max}}$ (Krahenbuhl *et al.*, 1985; Armstrong *et al.*, 1995). The methods of measuring cardiovascular fitness are detailed in Chapter 2 (pages 83-86). The gold standard approach is measurement in the laboratory with

full expired gas analysis during progressive workloads to exhaustion. In field and population studies, alternative methods of estimating $\text{VO}_{2\text{ max}}$ are required and the commonly used method, the 20 metre shuttle test (20-MST), will be discussed in Chapter 2 (pages 87-89). Prior to discussing the relationship between body composition and fitness, the data on fitness and mortality and cardiovascular risk factors will be presented.

1.3.3 Fitness, all-cause and cardiovascular mortality and risk factors in adults

In 1989, Blair *et al.* (1989) investigated the association between fitness and all-cause mortality in 10244 men and 3120 women. Fitness was measured by 'time to exhaustion' on a maximal treadmill exercise test, and subjects were classified into quintiles of fitness. The lowest risk of death was seen in those with the highest levels of fitness (the relative risk of death for men was 1.0 in those in the highest quintile compared to 3.44 in the lowest; in women the relative risk of death was 1.00 in the highest quintile, compared to 4.65 in the lowest quintile). In a later study by Blair *et al.* (1996), the strength of the association between fitness and all-cause mortality was compared to other risk factors, including smoking, hypertension, high cholesterol and weight. It was found that low fitness was associated with an equal or greater increase in mortality risk, compared to other risk factors (the relative risk of death for men was 1.52 and for women was 2.1 in the lowest quintile of fitness, which was similar to the relative risk of death for smoking which was 1.65 for men and 1.99 for women).

This protective effect of fitness from the adverse effects of obesity on health was seen by Ross and Katzmarzyk (2003) who investigated whether, for a given BMI, men and women with higher cardio-respiratory fitness have lower waist circumference and lower sum of skin

folds, compared to those with low cardio-respiratory fitness. In this study of 3719 males and 3854 females for a given BMI, both genders with high fitness levels had lower waist circumference and skin-folds compared to those with lower fitness ($P<0.001$).

It can be seen from these studies that low fitness is associated with all cause mortality and cardiovascular risk. Even in those with obesity, fitness appears to have some protective qualities against cardiovascular risk.

1.3.4 Physical fitness and cardiovascular risk factors in children

To date, no studies examining mortality and fitness in children have been published. However, there are a number of studies investigating fitness and cardiovascular risk factors.

A number of studies have examined the relationship between fitness and blood pressure in children. In the Oslo Youth Study, fitness, as predicted from heart rate during a sub-maximal exercise, was found to be inversely related to both systolic and diastolic blood pressure ($P<0.01$ for boys (systolic), $P<0.0001$ boys (diastolic) and $P<0.0001$ (systolic and diastolic) girls) (Tell and Vellar, 1988). As part of the Australian Schools Health and Fitness Survey, Dwyer and Gibbons (1994) assessed blood pressure, fitness and body fat in a representative sample of children aged 7 to 15 years. Fitness, as measured by physical work capacity at a heart rate of 170 bpm, was found to be related to systolic blood pressure ($P<0.001$). In younger subjects, Gutin *et al.* (1990) examined the relationship between blood pressure, fitness and body composition in 216 Hispanic children aged 5-6 years. Diastolic blood pressure was inversely related to fitness (measured by a sub-maximal test) for both genders ($P<0.05$). Sallis *et al.* (1988) studied fitness, as measured by predicted $\text{VO}_{2\text{ max}}$ on a sub-maximal cycle ergometer test in 268 adults and 290 children. Fitness was found to be

significantly related to blood pressure ($P<0.001$), as well as high density lipoprotein ($P<0.01$) and high density lipoprotein/low density lipoprotein ratio ($P<0.05$).

In contrast to the above findings, Guerra *et al.* (2002) found no relationship between fitness measured by the 20-MST and blood pressure in 529 Portuguese children aged 8-15 years. Multiple regression analysis revealed that systolic and diastolic blood pressure were explained by weight and age ($P<0.01$), and, in girls, percentage of fat influenced the variance in systolic blood pressure ($P<0.05$).

While the above cross-sectional studies investigated fitness at a point in time, other studies have looked at training effects on blood pressure in children. Hansen *et al.* (1991) examined the effect of physical training on fitness and blood pressure in 9-11 year olds. Sixty nine children with hypertension (above or equal the 95th percentile) and 68 normotensive children were randomised into an intervention or control group. The intervention consisted of physical training, with three extra PE lesson per week for 8 months. The training intervention was found to lower blood pressure and improve fitness in both normotensive and hypertensive children. Systolic and diastolic blood pressure in the training group fell significantly by 6.5 mmHg (95% CI, 3.2 to 9.9) and 4.1 mmHg (95% CI, 1.7 to 6.6) in the normotensive subjects ($P<0.05$) and by 4.9 mmHg (95% CI, 0.7 to 9.2) and 3.8 mmHg (95% CI, 0.9 to 6.6) in the hypertensive subjects ($P<0.05$).

The effect of an aerobic exercise training programme (with education) on weight control and blood pressure was investigated in 1,140 subjects aged 11-14 years who were randomly assigned to four treatment groups: exercise only, education only, exercise and education combined and a control group (McMurray *et al.*, 2002). There were small decreases in systolic and diastolic blood pressures in all but the control group, and the decrease was

significant for diastolic blood pressure in the exercise groups ($P<0.001$) when compared to the control and education only groups. There was no significant change in BMI, leading the authors to conclude that an exercise programme could have a positive effect on blood pressure, independent of any change in body weight.

Inflammatory markers such as fibrinogen, C-reactive protein (CRP), and interleukin-6 (IL-6) are important risk factors in atherosclerosis (St Pierre *et al.*, 2005) . Halle *et al.* (2004) investigated fitness and inflammatory markers, IL 6 and TNF-alpha, in obese and non-obese children and found that obese children had significantly higher concentrations of inflammatory markers ($P<0.01$). When the children were divided by fitness, it was found that fit but obese children had similar levels of inflammatory parameters as lean fit children, indicating that fitness counteracts inflammation associated with obesity. The association between physical fitness and CRP in children and adults was examined by Isasi *et al.* (2003), and it was found that fitness was inversely correlated to CRP in boys ($r=-0.32$, $P<0.01$) but not in girls.

Recently Hansen *et al.* (2005) in Denmark described the population values of cardiovascular disease risk factors in 6-7 year olds. Peak VO_2 , BP, body composition and physical activity (measured by accelerometry) were determined along with insulin, glucose and blood lipid levels. Fitness was associated with high density lipoprotein cholesterol ($r=0.14$; $P<0.01$) and physical activity ($r=0.12$; $P<0.01$).

The above results imply the importance of considering exercise in the prevention and management of hypertension in children. From the above evidence there appears to be a relationship between fitness and blood pressure in children, but further study is required to determine optimal training, in terms of frequency, intensity, time and type, to optimise the BP

lowering capacities of exercise. In addition, fitness appears to be positively related to inflammatory markers and arterial compliance. The following section will describe the relationship between body composition and fitness.

1.3.5 Body composition and physical fitness

In children, there is growing evidence of the importance of fitness in healthy body composition. Recently, a number of studies have been reported where the variables of body composition and fitness in children have been examined. A number of the studies in the last section investigating body composition included data on fitness in addition to physical activity, but in most cases the analysis included an adjustment for fitness in examining the relationship between body composition and activity. Others investigated the association of physical activity with both body composition and fitness. Ruiz *et al.* (2006) found that total physical activity was positively associated with fitness but the association between body composition and fitness was not examined. Andersen *et al.* (2006) also examined fitness in addition to physical activity, body composition and other cardiovascular risk factors but did not examine the specific association between body composition and fitness. Guerra *et al.* (2002) described the association between fitness and blood pressure and body composition in children, but again the associations examined in the report focused on the correlation between fitness and blood pressure.

In Portugal, Mota *et al.* (2006) examined the differences of cardio-respiratory fitness (CRF) among weight groups (non-obese, overweight and obese) and the association of CRF with body mass index in 255 children aged 8-10 years. Fitness was assessed by the 1-mile run test. The prevalence of overweight and obesity was similar for both boys and girls (30.5%, 29.1% and 13.2% and 12.6% respectively). There were no differences in body composition groups according to CRF in boys, but significant differences were found in girls ($P < 0.001$). It

was found that girls who were overweight or obese were likely to be unfit (OR =0.09, P=0.001), but no significant result was seen in boys. This gender difference is of interest and appears to be the opposite of the relationship between activity and body composition noted in boys (see section 1.2, page 27). An earlier study by the same group investigated the relationship between maturity status and body fatness, regional fat distribution and cardio-respiratory fitness in 494 children aged 8-16 years. With adjustment for maturity status, cardio-respiratory fitness was inversely associated with percentage body fat (estimated from skin-folds) (both genders $P<0.01$) (Mota *et al.*, 2002). These negative correlations between BMI and waist circumference and physical fitness were also found by Brunet *et al.* (2006) (most $P<0.05$), and the relationships were significantly greater in older children ($P<0.05$).

In obese children Nassis *et al.* (2005) investigated the association between fitness and both central and total body fat. Fitness was measured with the endurance shuttle-run test in a total of 1362 children aged 6-13 years. Anthropometric data included height, BMI and four skin-fold thickness. Children were placed into two groups: non-overweight and overweight/obese, based on the international cut off points (Cole *et al.*, 2000) and were also grouped into quintiles of fitness. Body fat was found to be lower in overweight/obese youths of high fitness compared to those of the same BMI category but low fitness ($P<0.01$), which suggests the protective effect of fitness on cardiovascular risk in the presence of obesity. One of the determinants of a risk factor is if reversal can be shown to occur, and a study in obese children has demonstrated this change. Carrel *et al.* (2005) investigated whether a school-based fitness programme could improve body composition in overweight children. Fifty overweight children were randomized to either lifestyle-focused, fitness-oriented gym classes or standard gym classes for 9 months. It was found that the treatment group demonstrated a significantly greater loss of body fat ($P=0.04$) and a greater increase in fitness ($P<0.01$).

Most of the above studies have been of a cross-sectional design, and therefore causality cannot be inferred, whereas the following studies involved follow-up of the subjects studied. In the US Kim *et al.* (2005) examined the relationship between fitness and body composition using a school surveillance system. Physical education teachers measured height, weight and fitness yearly from 2001 to 2003 in 6297 students aged 5-14 years. A prospective analysis was also done on 2927 subjects (aged 5-13 years) who were not overweight at baseline. Fitness was measured by five tests which included: an endurance run, abdominal strength, flexibility, upper body strength and agility. Underfit was defined as failing at least one of the five tests. The mean number of fitness tests passed was lower among subjects with a BMI over the 80th percentile. While this BMI did not identify overweight (which was set at > 95th percentile), it did indicate those on the higher end of normal body weight. Failure on the endurance run and the upper body strength test was associated with overweight in both genders. The endurance run was a significant predictor of overweight among girls (OR 2.0 (95% CI, 1.1 - 3.5)).

Johnson *et al.* (2000) examined whether aerobic fitness influenced weight gain in black and white children. One hundred and fifteen children were recruited (72 white and 43 black) to the study, and, at baseline, aerobic fitness and body composition were determined. Body composition was measured annually for 3-5 years. It was found that there was a significant negative relationship ($f(1,82)=3.92$) between aerobic fitness and increasing adiposity. With every increase in 0.1 l/min of fitness, there was a decrease of 0.081 kg fat per kg of lean mass gained.

In 1993, Watson assessed 1163 Irish school children aged between 7 and 13 years for height, weight, skin-fold thickness and aerobic endurance using the six minute run test. Measures were compared to 11-13 year olds from Northern Ireland, and endurance scores were

compared to international norms. It was found that Irish children were the same height as European children, but were heavier and had higher skin-folds. Aerobic endurance scores were 80% of international norms. High levels of cardiovascular fitness during childhood and adolescence have been associated with a healthier cardiovascular profile both during childhood and later in life (Boreham *et al.*, 1997; Brage *et al.*, 2004). While there appears to be a need for more research in the area of the protective effect on obesity of fitness and exercise training, in addition to the effects on other cardiovascular risk factors, the evidence so far suggests that attaining and maintaining fitness in children should be promoted. Unlike the relationship between body composition and activity, which has produced some conflicting results, in the small number of studies to date it appears that there is a relationship between body composition and fitness. However, the specifics of this relationship are not clear, and, as BMI represents a measure of both fat mass and fat-free mass, there is a need to measure body fat by other means in addition to BMI.

1.4: Levels of physical activity and fitness in children

In sections 1.2 and 1.3 the benefits of activity and fitness on body composition and cardiovascular health were presented. This section will detail reported levels of physical activity and fitness in children and the factors that are associated with these levels. At the end of the section studies that have investigated tracking of activity and fitness will be discussed.

1.4.1 Current levels of activity in children and related factors

Large scale studies that have used questionnaires to measure physical activity will be presented first. Studies using objective measures will then be discussed. Activity levels will be described in terms of the percentages meeting recommendations and in terms of minutes per day in different intensities of activity.

In 2001, the European Heart Health Initiative presented data on activity levels in European children. The majority of 11 year olds in EU states reported exercising twice a week or more, but considerable variations existed, e.g. 54% of girls in France were active at this level compared to 89% of girls in Northern Ireland, and 76% of boys in Norway compared to 93% of boys in Northern Ireland. In Belgium, levels of inactivity were found to be higher in girls than boys of 12 years of age, e.g. 6.3% of boys were active for less than one hour per week in comparison to 16.5% of girls, and in 17 year olds 15.2 % of girls and 19% of boys were found to be inactive. In Denmark, boys and girls (7-15 years) were active for an average of 36 minutes daily (excluding walking and cycling as transport) and 71% of all children engaged in organised sports activity, but this participation decreased with age. In England, 61% of males and 42% of females achieved the recommended one hour of moderate activity per day, whereas in Finland 40% of boys and 27% of girls met this recommendation. In the Netherlands, data on sporting activity showed that 70-80% of those aged 6-24 years played

sport on a regular basis, with males being more active than females, and a decrease in participation occurred with age. In Norway, 85% of 9 year old boys and 75% of girls were active for one hour per day. In Spain 67% of 15-17 year olds did some form of physical activity at least three times per week, and participation levels were largely unchanged over the last 10 years.

All measures of physical activity in the studies that were considered for the above paper were done by self-report/ questionnaire. The authors did state that differences in the way questions were asked in the different countries may have affected answers. In addition, more data were provided from some countries than others, and therefore the data may appear somewhat unbalanced. It is difficult to compare the findings from one country to another due to the different age groups and dimensions of physical activity that were measured. In all countries, boys were more active than girls, and in most countries time spent in activity decreased with increasing age. In some countries, polarisation of activity was seen in adolescents where, alongside an increase in the number of inactive children, there was an increase in the proportion reporting regular vigorous activity. An argument could be made for a study using the same methodology in a number of European countries as this would permit comparisons. The European Heart Study has gone some way towards this in 9 and 15 year olds (Riddoch *et al.*, 2004).

In Ireland, the second National Health & Lifestyle Surveys (2003) contains data from the Survey of Lifestyle, Attitudes and Nutrition (SLAN) & The Irish Health Behaviour in School-Aged Children Survey (HBSC). The former concentrates on the Irish adult population, while the latter is part of a wider World Health Organisation (European)

collaborative study with 32 countries involved. The protocol for the HBSC included samples in the 11, 13 and 15 year old age groups.

In the second report (2003) vigorous exercise rates were higher among boys than girls of all ages, and the gap doubled by the mid-teen years, where a number of girls were reporting no activity at all. In terms of number of hours per week spent exercising, 48% (59% of boys and 38% of girls) of children reported exercising four or more times per week. Exercising four or more times per week decreased from 59% in 10-11 years to 35% in 15-17 years, with the decrease being more marked in girls. Twelve percent of respondents reported exercising less than weekly. Inactivity rates in girls were higher than in boys and rose sharply from the age of 15 years.

The studies above used questionnaires to measure physical activity and were mainly performed on large representative samples. An observation study in a smaller population was performed by Sleaf and Warburton (1996), who measured physical activity in 93 children aged 5-11 years and found only 21% of children engaged in sustained 20 minute periods of moderate to vigorous physical activity (MVPA). However, 95% engaged in 5 minute periods of MVPA. Thus, while observational studies may be limited in terms of numbers of subjects that can be studied, additional details, such as type and the length of specific activity periods, can be obtained from such studies.

The following studies investigating activity levels used objective measures and therefore were performed on smaller numbers of subjects, and, in many cases, the samples may not have been representative of the population in question. Some of the objective measures used permitted the definition of time spent in specific intensities of activity. Sleaf and Tolfrey (2001) used heart rate monitoring to measure cumulative activity in 79 children of 9-12 years.

Results showed that the children did engage in activities that resulted in intensities greater than 120 bpm and 75% above the resting heart rate, and the authors concluded that the subjects met the UK and US recommendations for daily activity. The subjects, however, did not experience a minimum of one hour of exercise at an intensity of 160 bpm or above (vigorous activity) and therefore may not have performed sufficient activity for cardio-respiratory fitness. While heart rate monitoring is an objective measure of physical activity, it is difficult to compare findings from one study to another due to the different values for heart rate described as the minimal recommendations (see Chapter 2, pages 80-81).

As part of the European Youth Heart Study, Riddoch *et al.* (2004) assessed physical activity levels in 2,185 children, aged 9 and 15 years from Denmark, Portugal, Estonia and Norway. Activity was measured with uni-axial accelerometers, and the recommendations used were “a minimum daily accumulation of at least 60 minutes of moderate intensity activity”. At the age of 9 years 97.4% of boys and 97.6% of girls achieved the minimal health related physical activity recommendations, but by 15 years these figures were 81.9% and 62%.

In a separate study in Portugal, Santos *et al.* (2003) measured activity levels in 157 children aged 8-15 years and found that all age and gender groups, other than the females of 11-13 years, achieved the minimal recommendation of 60 minutes per day spent in moderate to vigorous physical activity.

Accelerometry was also used by Pate *et al.* (2004) to investigate physical activity in 281 preschool children in 9 preschools in the US. Subjects had activity measured for 4.4 hours per day for an average of 6.6 days. In terms of minutes per hour spent in the different intensities of activity, it was found that the sample spent a mean of 41.7 ± 5.8 minutes sedentary, 10.5 ± 3.2 minutes in light activity, 7.7 ± 3.1 minutes in moderate to vigorous activity and 1.9 ± 1.1

minutes in vigorous activity. A limitation to this study was that only measuring activity over a few hours during the school day may not be representative of the whole day. If the 4.4 hours was representative, the children would have been found to adhere to recommended levels of activity.

In conclusion, the above studies measured activity levels, and a number have compared findings to recommended guidelines. Most of these studies were performed prior to 2005, prior to the recommendation of 60 minutes per day by Strong *et al.* (2005). In the studies where adherence to recommendations was measured, it was generally found that children engaged in levels of physical activity which met recommendations.

1.4.2. Contribution of transport to school to activity levels

Active commuting to school is a means by which many children could partly achieve the recommended level of daily physical activity. In addition, it may encourage the habit of lifestyle physical activity that can be continued into adulthood.

A multinational study in 1997 examined the differences in children's patterns of transport to school in cities in Australia, Canada, New Zealand, Sweden and USA. The patterns of travel of children aged 6 and 9 years were evaluated by a parent-child questionnaire. Responses were obtained from the parents of 13423 children, and distinct patterns were found. In the Australasian cities, there was a high level of car use and low levels of cycling and walking. More than one third of the children studied in this area spent less than 5 minutes walking each day. In Canada, walking and public transport were the most common methods of transport, and in Sweden walking and cycling were the most popular. In comparison with children from the North American and Australasian cities, those from Sweden spent more time walking, with 87% engaging in at least 5 minutes per day walking (Roberts *et al.*, 1997).

In the US, Evenson et al. (2003) examined the prevalence and correlates of walking and cycling to school in children from 60 middle schools and 62 high schools in North Carolina. In middle school students, 10.5% either walked or cycled to school, in comparison to 7.7% in high school students. Both walking and cycling were more prevalent in nonwhites. Higher parental education was associated with a reduced odds ratio of walking to school in high school students by 0.54. These results suggest that, among those of higher affluence in the area studied, there is less likelihood of the child walking to school.

In addition to the number of children using active transport to school, the studies below also measured the contribution which the journey made to the overall activity level. Tudor-Locke *et al.* (2003) objectively measured physical activity in 1518 Filipino adolescents aged 14-16 years and compared the activity levels of those who walked to school with those who travelled by car (or by a combination of the two). Physical activity was measured by the Caltrac accelerometer. In males, 46.8% walked to school, 23.2% took motorised transport and 30% used a combination. In females, 36.6% walked, 21.4% took motorized transport and 42% used a combination. The addition of walking to school increased energy expenditure in regular activity by 44.2 kcal/day in boys and 33.2 kcal/day in girls. Over a year this difference was calculated by the authors to be 8840 kcal in boys and 6640 kcal in girls, which would account for a 2-3 lb weight loss if all other parameters were kept constant.

A smaller contribution to overall activity was seen in a study by Harten and Olds (2004), who examined patterns of active transport in Australian 11-12 year olds and quantified the impact of active transport on overall daily energy expenditure. Each child recalled their trips on two school days and one non-school day and completed a computerised activity recall. Levels of active transport were found to be low, with 26 % of children engaging in no active transport over the study days. Overall, active transport contributed to 1.3 % of daily energy

expenditure and therefore did not significantly increase the overall activity measure. Another Australian study by Ziviani *et al.* (2004) investigated the extent to which children walked to and from primary school and surveyed parents to identify factors that might influence this behaviour. It was found that the mode of transport to schools was influenced by the parents' perception of the importance of physical activity, including how they themselves had travelled to school, and the distance the child lived from the school (Ziviani *et al.*, 2004).

Cooper *et al.* (2003) investigated the contribution of commuting to school to the overall activity level. One hundred and fourteen primary schoolchildren (mean age 10.4 ± 0.8 years) from all socio-economic classes in Bristol (UK) wore an accelerometer for 7 days and completed a questionnaire. Sixty five percent of subjects walked to school, and these subjects were significantly more active than those who travelled by car (mean accelerometer counts per minute for those who walked 712.0 ± 206.7 versus 629 ± 207.2 , $P=0.05$). Boys who walked to school were also more active after school ($P<0.05$). In examining the actual data the increase in number of minutes per day in moderate to vigorous physical activity, which was the result of walking to school, was only 10.6 minutes, but the overall difference in terms of minutes per day in moderate to vigorous physical activity was over 20 minutes. These results suggest that walking to school contributes to being generally more active, particularly in boys, where the difference was almost 45 minutes per day.

A study involving a larger number of children reported findings similar to the above. Cooper *et al.* (2005), as part of the European Youth Heart Study, investigated the impact of travel mode on physical activity levels in 332 Danish children aged 9.7 ± 0.4 years who wore an accelerometer and answered questions on their travel habits. Children who walked to school were significantly more active than those who travelled to school by car (accelerometer counts per minute 667.7 ± 233.7 versus 557.3 ± 191.4 , $P=0.01$). While those

who cycled to school had higher accelerometer counts than those who travelled by car, the difference was not found to be significant. When the genders were considered separately, boys who walked or cycled were significantly more active than those who travelled by car (walking: 732.2 ± 253.1 versus 592.8 ± 193.9 , $P=0.007$), cycling: 712.6 ± 249.1 versus 592.8 ± 193.9 , $P=0.013$). In girls, walking, but not cycling, was significantly associated with higher daily physical activity levels (606.3 ± 197.7 versus 523.4 ± 185.0 , $P=0.05$). A similar study in adolescents aged 13-14 years by Alexander *et al.* (2005) investigated moderate to vigorous physical activity (by accelerometry) and means of transport to school. The mean number of minutes per day of moderate to vigorous physical activity outside school was significantly higher in those who walked both to and from school, compared to those who travelled by motorised transport (mean of 17 minutes (95% CI, 5.2 to 28.9))

Walking or cycling to school has been found to be associated with higher overall levels of physical activity, with only some of the increase being due to the actual journey. While active commuting to school by younger children who are reasonably active may contribute little to overall activity levels, the formation of such a habit may be of greater impact in adolescence and adulthood, when overall activity levels decline. In addition, it has been found that walking to school has a positive effect on overall daily activity to an extent that is greater than the time spent walking.

1.4.3. Contribution of physical education at school to activity levels

As children appear to become more sedentary in school as they progress through the years, it may be important to increase the time spent at PE. Physical education in schools contributes to the total weekly activity level of children, and also may affect the child's interest and approach to physical activity generally by introducing them to a wide range of activities. A greater number of PE lessons has been found to correlate with increased participation in

active pursuits (Gordon-Larsen *et al.*, 2000). There is concern that a large proportion of the overall time in PE is spent in management and organisation rather than physical activity. A study in Australia analysed 231 PE lessons in 18 randomly selected schools and found that children spent 36.7% of time in moderate to vigorous and 12.9% of time in vigorous activity (Barnett *et al.*, 2002).

The question of compensating with increased activity after school on days of restricted activity in school was investigated by Dale *et al.* (2000). Physical activity was measured by accelerometers in 76 children in third and fourth grade. Children did not compensate for sedentary school days by increasing physical activity after school, which is a cause for concern when there are few opportunities in school for activity. However, this was another small study with a specific, rather than representative, sample.

There may be concern that increased time in PE may negatively impact on academic performance due to time taken from the academic components of the curriculum. However, this was not found in a study in Australia where 45-60 minutes per day were lost from formal teaching time and spent on daily physical activity in 10 year olds. There was no decrease in academic performance in reading or arithmetic tests but considerable beneficial effects on fitness, blood pressure and body composition (Dwyer *et al.*, 1983).

1.4.4 Other factors related to physical activity levels

There are a number of factors that may be associated with activity levels which will be detailed below. These include age and gender, school days versus free days, safety concerns, environmental and cultural factors.

Gender differences in terms of physical activity levels have been investigated in a number of studies in many countries, in children ranging in age from 4 years to 16 years, and it has been reported that boys engage in greater levels of overall physical activity than girls (Le Masurier and Corbin, 2006; Gavarry *et al.*, 2003; Armstrong *et al.*, 1990; Riddoch *et al.*, 2004; Santos *et al.*, 2003) and, in addition, spend more time in vigorous physical activity (Gavarry *et al.*, 2003; Kelly *et al.*, 2005; Riddoch *et al.*, 2004; Pate *et al.*, 2004 ; Santos *et al.*, 2003; Sullivan., 2002). In reports where children of a wide age range were studied, it was found that objectively measured activity levels decreased with age in two (Gavarry *et al.*, 2003; Riddoch *et al.*, 2004) but increased with age in another (Santos *et al.*, 2003). In most of the studies, it was found that girls engage in less overall activity than boys and both genders do less in later teenage years compared to childhood and early adolescence.

Most of the studies discussed above have been performed in children aged 10 years and over. Pate *et al.* (2004) did examine activity levels in preschool children, but few have addressed activity levels in school children aged 6 –9 years. At this age the child is often introduced to different sporting activities and may start to have some independence of choice of activity.

The studies discussed so far have been of a quantitative nature. To investigate the impact of environmental and cultural factors on activity a number of studies, some of which have used qualitative methods, have been performed. Thompson *et al.* (2001) investigated barriers and support to physical activity among American Indian children, by means of observation, in-depth interviews and focus groups with children and their parents. The authors concluded that barriers in schools included a lack of facilities, equipment and trained PE staff. Weather conditions, safety concerns and time limitations due to homework were described as barriers to physical activity by children and parents. Parents may discourage activities that they perceive as high injury risk (Boufous *et al.*, 2004), and safety concerns about particular urban

neighbourhoods are associated with lower activity levels (Molnar *et al.*, 2004). While one study comparing activity levels in those from urban and rural areas found higher levels in those from rural areas (Proctor *et al.*, 1996), another found that in summer children from rural areas were more active, but the opposite occurred in winter months (Loucaides *et al.*, 2004). As part of the Belgian Luxembourg Child Study II, Guillaume *et al.* (1997) found significantly less physical activity (girls $P=0.098$, boys $P=0.004$) and more television watching (girls $P=0.028$, boys $P=0.046$) in children in the most rural areas of the community studied.

One reason for the decreasing levels of physical activity in children may be the increased choice of leisure pursuits, including sedentary activities such as TV/ computer games. A longitudinal study by Hancox *et al.* (2004) followed 1000 subjects born in 1972-1973 in New Zealand at regular intervals and found the mean TV viewing hours per day were 1.91 ± 1.23 in boys and 1.91 ± 1.35 in 5 year old boys and girls, and these progressively increased up to a peak at 13 years where figures were 3.86 ± 1.57 hours and 3.54 ± 1.48 hours. At 15 years of age the values were 3.58 ± 1.79 and 3.19 ± 1.71 hours for boys and girls, respectively. At 15 years of age physical activity was measured by questionnaire and it was found to be significantly negatively correlated with hours of adolescent TV viewing ($P=0.01$).

There are many environmental influences on physical activity in children, and it is difficult to compare studies from varying parts of the world, due to differences in transport, facilities in schools and socio-economic influences. Even within a community, parental influences may lead to considerable differences in physical activity opportunities and encouragement. Many reasons are given as to why children today spend less time engaged in physical activity. Possible explanations are the choice of sedentary activities, including TV and computer games, safety concerns and lack of facilities within easy access. Age and gender appear to

have significant impact on physical activity levels with boys engaging in higher levels than girls, and, in both, activity declines through adolescence.

1.4.5 Current levels of fitness in children

This sub-section will present details on current levels of fitness in children and how activity may affect fitness. Fitness is partly genetically determined but can be improved by activity (Riddoch and Boreham, 2000). There are multiple dimensions to physical fitness, and generally studies investigating health-related physical fitness have concentrated on the components of aerobic capacity and body composition.

A number of studies have been reviewed regarding fitness levels of children and the details of age, country, numbers, method of testing and results are presented in table 1.1

Table 1.1: Recent fitness studies in children

Age range	Country	Number studied	Method of testing	Results VO ₂ peak or VO ₂ max in ml/min/kg	Reference
7.9-11.1 years	Sweden	248	Maximum exercise test on bicycle ergometer with expired gases	Boys: 42±7.4 Girls: 36±6.3	Dencker <i>et al.</i> (2005)
12-15 years	Australia	18,631	20- MST	Boys: 46.2±6.5-47.4±6.9 Girls: 39.2±5.9-42.6±5.1	Tomkinson <i>et al.</i> (2003)
9 years	Denmark	(a) 1985-1986 (b) 1997-1998	maximal cycle ergometer test	Boys (a) : 49 ±6 Girls (a): 43±6 Boys (b): 47±8 Girls (b): 42 ±7	Wedderkopp <i>et al.</i> (2004)
11-16 years	Australia (Tasmania)	6061	20-MST	Boys 16 years: 50.4 Girls 13-15 years: 40.6	Cooley and McNaughton, (1999)
9 and 10 year old	Tanzania and Norway	156 (Tanzania) 379 (Norway)	Indirect maximal watt cycle ergometer test both groups. 20-MST Tanzanian children (n=276) *	Tanzanian boys: 44.6 (43.3 to 45.8) Tanzanian girls: 37.2 (36.1 to 38.3) Norwegian boys: 45.9 (44.9 to 46.9) Norwegian girls: 40.5 (39.5 to 41.5) Tanzanian boys* 57.5 (56.9 to 58.0) Tanzanian girls * 54.8 (55.6 to 56.4)	Aandstad <i>et al.</i> (2006)
6-7 year olds	Denmark	369 boys and 327 girls	Run to exhaustion on a treadmill	Boys: 48.5 ±5.9 Girls: 44.8 ±5.4	Hansen <i>et al.</i> (2005)
8-15 year olds	Portugal	529 children	20-MST	Boys 8-9 years : 48.8 5 ±3.2 Boys 14-15 years: 50.5 ±4.2 Girls 8-9 years: 47.0 ±2.5 Girls 14-15 years: 44.0 ±3.7	Guerra <i>et al.</i> (2002)
8-11 years	Sweden	248 children	Maximum exercise test on a bicycle ergometer	Boys: 42 ± 7.4 Girls: 36 ± 6.3	Dencker <i>et al.</i> (2006)
8-16 years	Portugal	494 children	20-MST	Boys 9.1 years: 48.2 ± 3.4 Boys 15.1 years: 50.9 ± 4.1 Girls 9.2 years: 46.7 ± 2.8 Girls 15.8 years: 42.1 7 ± 4.1	Mota <i>et al.</i> (2002)

Wedderkopp *et al.* (2004) analysed the secular trends in fitness and obesity in Danish children aged 9 years from two representative population studies that were 12 years apart. It was found that boys had a lower physical fitness in 1997-98 than in 1985-86 ($P < 0.001$). In girls there was no overall change in fitness. Furthermore, of note was that in both genders there was an increase in polarization, i.e. the difference between the fit and unfit, between the two studies (boys' fitness $P = 0.000$, girls' fitness $P = 0.0002$).

A very large study on fitness in 12-15 year olds was performed in Australia as part of the Australian Sports Commission's Talent Search program (Tomkinson *et al.*, 2003). The sampling procedure used in the study was that all 186 secondary schools in the metropolitan area of South Australia were approached to participate in the Talent Search scheme. The average acceptance rate was 16% (range 6% - 35%) and therefore the representation of the sample may be questioned as it could be argued that schools who were more interested in sport were more likely to become involved in the study so a degree of self selection may have occurred. A total of 18631 children aged 12-15 years had fitness tested by the 20-MST in 1995-96 and again in 1999-2000. When data were compared to those from other countries, these children demonstrated poor to average aerobic fitness. When the 20-MST results from 1995-1996 were compared to 1999-2000 there were significant declines across the years in both genders of between 0.19 ($P = 0.04$) to 0.36 ($P < 0.001$) ml O_2 /kg/min. The percentage change ranged from 0.6% in 12 and 13 year olds of both genders to 1.3% in 14 and 15 year old boys. The authors suggest that this may be due in part to reduced physical activity, however physical activity was not measured.

1.4.6 The relationship between activity levels and fitness in children

The papers evaluated in this sub-section have generally concentrated on the components of aerobic capacity and body composition and not flexibility, strength and balance. It is appreciated that all these components contribute to overall fitness and may to a degree be interdependent. Difficulties arise when studying the influence of physical activity or training on aerobic capacity, due to the difficulties in quantifying overall physical activity in children. The difficulty is compounded when many months or years of quantification of overall activity is required. The limitations associated with many of the techniques of measuring activity are presented in Chapter 2. A number of factors affect $VO_{2\text{ peak}}$, and these include genetic factors, state of training, body size and composition, gender and age. The genetic influence is estimated to account for 10-30 % of the variance in $VO_{2\text{ max}}$. While a vigorous exercise programme will increase fitness, independent of genetic background, the limit for fitness is genetically determined (Mc Ardle *et al.*, 1996).

$VO_{2\text{ max}}$ is the traditional method of measuring increasing oxygen uptake with increasing exercise intensity up to a point beyond which no further increase in VO_2 is observed, even when the subject increases to a higher exercise intensity, and a plateau in VO_2 occurs. In children, very few demonstrate a VO_2 plateau. The term $VO_{2\text{ max}}$ by convention implies a plateau, and therefore in paediatric exercise science, the term $VO_{2\text{ peak}}$ is often used for the highest oxygen consumption during an exercise test to exhaustion (Armstrong and van Mechelen, 2000). These terms will be used interchangeably in this thesis, as the studies reviewed have used both.

The relationship between activity levels and fitness was investigated in 257 children aged 5.7-18.5 years by Weymans and Reybrouck in 1989. Fitness was measured by a graded

exercise test in a laboratory on a treadmill and expressed as the ventilatory threshold (defined as the highest exercise intensity before a disproportionate increase in pulmonary ventilation relative to oxygen uptake). Habitual physical activity was measured by means of a standardised questionnaire. Children were asked about participation in PE at school, sports during holidays and weekends, hobbies and team sports, the number of hours spent watching television and transport to school. Except during puberty, boys who were more active had a higher aerobic capacity compared to less active ones. In girls, habitual physical activity was low, and no relationship with exercise capacity was seen. However, as activity was measured by questionnaire, dimensions such as intensity of activity and spontaneous activity would not have been captured, so it was not possible to examine a linear relationship.

Sallis *et al.* (1993) examined the relationship between habitual physical activity and components of physical fitness, including a one mile run, pull ups, sit ups and the sit and reach test. Activity as measured both by self-report and accelerometry (1 day) was significantly associated with the mile run ($P < 0.001$) in the 528 children studied. The physical activity index was significantly associated with all fitness components (canonical correlation = 0.29, $P < 0.001$). However, the objective measure of activity was only performed for one day, and it could be queried how representative a single day is, as four days of activity has been found to be the required length of time to determine habitual activity levels in children (Trost *et al.*, 2003).

In a longitudinal study over 15 years, Kemper *et al.* (2001) tested the hypothesis that daily physical activity over 15 years had a beneficial effect on aerobic fitness. This investigation was part of the Amsterdam Growth and Health Longitudinal Study. Daily physical activity was measured by questionnaire, and aerobic fitness was assessed by a maximal treadmill running test in 181 subjects at 13 and 27 years. A significant relationship was seen between

daily activity and fitness ($P<0.01$), leading the authors to conclude that the development of aerobic fitness between 13 and 27 years is independently and positively related to daily physical activity.

In adolescents, Huang and Malina (2002) examined the relationship between physical activity and health-related physical fitness in 282 subjects. Physical activity was measured using 24 hour activity records, and fitness was measured by a number of tests, with the one-mile run used for cardiorespiratory endurance. A significant relationship was found between physical activity and the one-mile run for both genders ($P<0.01$). Once again activity was only measured over one day which may not be representative of overall activity.

Le Masurier and Corbin (2006) examined if steps per day varied based on aerobic fitness in middle school students (112 girls and 111 boys). The relationship between physical activity and aerobic fitness was moderate (0.35; $P<0.01$). The data did show significant differences in accumulated steps per day in students of varying fitness levels. It is unclear if improved fitness is the cause or the result of higher amounts of activity, and such would indicate that longitudinal studies are needed. A limitation to the assessment of physical activity for this study was the inability to determine intensity of activity.

Dencker *et al.* (2006) reported that no study had used direct measurement of maximum oxygen uptake and related this to physical activity intensities by accelerometers. Therefore the authors investigated the relationship between the two in 140 boys and 108 girls and found that maximum oxygen uptake was correlated with mean accelerometer counts ($r=0.23$, $P<0.05$, both genders) and time spent in vigorous activity ($r=0.32$ boys and $r=0.35$ girls, both $P<0.05$). This appears to be the first study to objectively measure both activity and fitness.

The associations of total physical activity and intensity levels to cardiovascular fitness were examined by Ruiz *et al.* (2006) using accelerometry. Fitness was measured by a maximal ergometer bike test, and physical activity was measured over four days by accelerometry. Subjects were divided into 5 groups on the basis of time spent in vigorous physical activity. A significant association was found between activity group and fitness ($P < 0.001$). Those children who engaged in > 40 min/day of vigorous physical activity had higher fitness than those who engaged in less than 18 mins/day ($P = 0.003$).

The studies described above suggest that there is some relationship between activity and fitness, but the cross-sectional nature of most of this work does not allow causal inferences to be made. There is a need for longitudinal studies to determine how changes in activity affect fitness.

1.4.7 Tracking of fitness and activity levels in children

It has been suggested that activity levels track from childhood to adulthood and therefore it is important to establish patterns of activity in the young. Tracking of fitness and activity have not been extensively studied, probably due to the difficulties associated with such follow-up, but two studies will be discussed (Telema *et al.*, 2005; Boreham *et al.*, 2004 (b)). Telema *et al.* (2005) investigated stability of physical activity from childhood and adolescence to adulthood, as part of The Cardiovascular Risk in Young Finns Study. Tracking of physical activity was studied in 1563 subjects who in 2001 were aged 24-39 years and had been in the study since 1980 when aged 3-18 years. Physical activity was measured by a questionnaire, and a physical activity index was calculated. In males, the correlation coefficients for the 21 year period ranged from 0.33 ($P < 0.01$) to 0.44 ($P < 0.01$) and ranged from 0.14 (NS) to 0.26 ($P < 0.01$) in females. The correlations were higher over shorter time frames. Generally, tracking of physical activity from childhood to adulthood was lower in females than males. In

Northern Ireland, as part of the Northern Ireland Young Hearts Project, Boreham *et al.* (2004 (b)) investigated tracking of physical activity and fitness between adolescence and adulthood. Subjects were assessed at 15 years of age (245 males and 231 females) and again at the age of 22 years. At both points, BMI and skin-fold thicknesses were measured, and physical activity and diet were assessed by questionnaire. At 15 years, subjects were ranked into low, medium or high categories for fitness, and similar categories were defined at 22 years. Tracking of fitness was poor in both genders. Tracking of physical activity in males was fair but poor in females.

While the above studies investigated subjects over a prolonged time period which extended from childhood to adulthood, the following two studies have examined changes during childhood/adolescence. Treuth *et al.* (2004) investigated whether physical activity and fitness changed in 91 girls from 8 to 10 years of age. Both physical fitness and activity remained constant over the study time. Over a somewhat longer period, Kimm *et al.* (2002) studied physical activity in 1166 black and white girls in the US during adolescence. Physical activity was assessed (by questionnaire) at 9 or 10 years and later at 18 or 19 years. Substantial decreases in physical activity were seen in both groups, but there was a greater decline in black girls. The mean activity scores for black and white girls were 27.3 and 30.8 MET/hr/wk at baseline, but these had decreased to 0 MET/hr/wk and 11.0 MET/hr/wk by year ten of the study. By the age of 16/17 years, 56% of black and 31% of white girls reported no leisure time physical activity. Janz *et al.* (2005) examined activity intensities and patterns during a 3 year period in a population-based study, using accelerometry and survey methods, in subjects of 5.6 years at the beginning of the study and 8.6 years at follow up. Over the three year period, the correlation coefficients between baseline and follow-up activity measurements were low to moderate ($r=0.18$ to 0.39). Sedentary behaviour was more predictable than overall activity and tended to be more stable ($r=0.37$ to 0.52).

These results of the above studies imply that there is limited tracking of physical activity, but, due to the limited number of studies, it is difficult to be conclusive. It appears that boys engage in greater levels of activity than girls, and levels decrease with age as the children enter the teenage years. There are many factors influencing physical activity levels, and these include age, gender, transport to school, PE resources, environmental influences and sedentary activities. In the studies that have investigated levels of physical activity in children, it appears that the majority of subjects adhered to recommended activity levels of the time. The studies have mainly focused on those over 10 years and none in younger children at the time of the design of Study 1.

1.5: Summary of preceding sections

Obesity has increased in all industrialised countries, and, while there are limited data on Ireland, there is little reason to believe the figures would be different to those from UK and Europe. In Europe, the US and much of the developing world, the incidence of obesity in children has increased significantly in recent years (IOTF, 2005).

In addition to the long term consequences of ischaemic heart disease and diabetes, there are short term health consequences of obesity in childhood. There is a strong association between obesity and insulin resistance, and, while the numbers reported of those with type-2 diabetes are small at this point in time, it is believed that this will increase with the obesity epidemic. Cardiovascular risk factors are associated with overweight and obesity in childhood (Freedman *et al.*, 1999 b), and endothelial function is abnormal in severely obese (Tounian *et al.*, 2001).

While much is known about the beneficial effects of physical activity in the prevention of cardiovascular and other acquired diseases, it is believed that there are unprecedented levels of low physical activity and inactivity in populations in the developed world (Popkin, 2004). There is a popular belief that the current generation of children is less active than the previous generation and that this has been one of the main contributors to the “obesity epidemic”.

There is considerable evidence supporting the risks of inactivity on all cause and cardiovascular mortality in adults. In children, evidence of the link is lacking, probably due to the lack of longitudinal studies. There is, however, evidence supporting the beneficial effect of physical activity on a number of cardiovascular parameters in the young. The relationship between body composition and the intensity of activity needs to be examined.

In addition to the benefits of physical activity in adults, a strong inverse relationship for all-cause mortality across fitness categories has been demonstrated (Blair *et al.*, 1989). In those with obesity, fitness has protective health benefits (Ross and Katzmarzyk, 2003). There are considerably fewer data on fitness and cardiovascular risk in children, but a positive association between fitness and blood pressure has been seen in a cross-sectional study of 5-6 year old children (Gutin *et al.*, 1990). Fitness appears to be protective against increased body fat in children, and, even in those overweight, fitness is related to less body fat in children (Nassis *et al.*, 2005) and lower CRP in boys (Issai *et al.*, 2003). The relationship between body composition and fitness in children requires investigation.

The central questions addressed in this thesis are the relationships between body composition and both physical activity and fitness in children. These questions are of particular importance and required investigation because of the epidemic of obesity, which includes childhood obesity. If relationships exist, they need to be determined so that both preventative measures and management options can be put in place. The age group of particular interest is 7-10 year olds as at this age children commence regular activities but have not reached puberty. With puberty there is often a fall in physical activity and change in fitness due to increased muscle mass occurs. Recent data on age of puberty in Northern Europe indicates that the mean age of breast development in girls is between 10.7 and 11.2 years, with menarche occurring between 13.1 and 13.5 years (Parent *et al.*, 2003). In a recent study in Turkish boys the mean age of onset of puberty was 11.6 ± 1.2 years (Bundak *et al.*, 2006).

The evidence of beneficial effects of activity and fitness has led to a number of bodies recommending that all adults accumulate at least 30 minutes of activity on most, and

preferably all, days of the week. The guidelines for children are an accumulation of 60 minutes and up to several hours of moderate to vigorous activity daily.

Generally, boys appear to be more active than girls, and, in both genders, activity decreases with age. There are few data on changing activity levels in children, despite estimates being made indirectly by calculating time spent sedentary, e.g. watching television. There is limited evidence to support the contention that activity and/or fitness levels are either inadequate or declining in children. There are no large studies prior to 2003 investigating activity levels in children of 7-10 years. There is a lack of hard data on activity levels over the past 30 years, so it cannot be determined if children are engaging in less physical activity now.

1.6: Objectives of this thesis

This thesis investigates the inter-relationship between body composition, physical activity and physical fitness. The quantification of physical activity is difficult, and the measurement properties of a new accelerometer are investigated. The percentage of children meeting current activity recommendations is investigated.

Methods of sampling, study designs and measures of the variables investigated are presented in Chapter 2. Study one (Chapter 3) investigates physical activity levels in Dublin school children of 7-9 years. Study two (Chapter 4) details studies performed on children (aged 7-12 years) in the laboratory on the validity of the RT3 accelerometer to measure inactivity, walking and running. Study three investigates the relationship between body composition and physical activity, physical fitness and blood pressure in 7-9.9 year old children (Chapter 5). Study four (Chapter 6) investigates physical activity levels in children with obesity. In the Discussion (Chapter 7) the results of the studies are considered together in the context of similar international studies, and directions for further investigation in this area are suggested.

CHAPTER 2: METHODS

This chapter details study designs, methods of sampling and measures of the variables to be investigated in the studies in this thesis. An introduction to data analysis is also presented. The specifics of design, sampling, measures and data analysis related to the individual studies are presented in the relevant chapters which follow.

2.1 Background research methodology

2.1.1 Research Designs

Study designs in medicine can generally be divided into those that are observational and those that are experimental. Observational studies are used to determine an existing situation, whereas experimental studies are used where the results of a specific treatment require investigation (Gordis, 2004). The natural history of disease, and its causes and distribution, may be examined using observational methods. Unlike experimental studies, it is difficult to arrive at a definite conclusion in observational studies as cause and effect cannot be distinguished (Bland, 2000). The study designs that will be detailed in the following pages include cross - sectional surveys, cohort studies and case - control studies.

A cross - sectional study is a survey of a population at a single time point. The cross - sectional study is, therefore, a snapshot of that time period. Cross - sectional studies are useful in determining the prevalence of disease risk factors in a defined population (Sahai and Khurshid, 1996), and may also be used in the measurement of current health status in a population and in health service planning, e.g. mass screening programmes. Such studies do not permit the determination of a relationship between cause and effect as measures of the exposure to risk factors and the presence or absence of disease are made at a point in time (Jekel *et al.*, 2001). Repeated cross-sectional surveys over time can be used to measure

changes in risk factors and changes in the disease frequency. The data from cross - sectional studies can be used to generate hypotheses, but the effectiveness of interventions cannot be evaluated in this way. An example of a cross - sectional study would be comparing body composition with physical activity levels.

In a case - control study, a comparison between the frequency of a risk factor among cases is compared to the frequency of the risk factor in controls (Sahai and Khurshid, 1996). In such a study, a group of subjects with a specific condition (the cases) is compared to another group without the condition (the controls) (Campbell and Machin, 1999). The exposure of each subject to the factor under investigation is determined, and the difference between the two groups is examined (Bland, 2000). An example of a case - control study would be measurement of blood pressure and cholesterol in obese adolescents who were matched with a control group of adolescents of normal weight (Mc Murray *et al.*, 1995).

In cohort studies, the group to be studied is identified and subjects are then chosen depending on whether or not they have been exposed to the risk factor or through a random sample from the population (Vetter and Mathews, 1999). The subjects in the cohort selected are followed up over time to determine if they develop the condition of interest (e.g. obesity) and if the risk factors identified at the beginning of the study predict the development of the condition. These studies can take considerable time as the researchers wait for the future events to occur. Cohort studies are very useful in the evaluation of long term, non-infectious diseases (e.g. CHD and cancer). One disadvantage of a cohort study is that only the factors measured at the outset can be evaluated. Another disadvantage is the high cost and significant resources as subjects may need to be tracked over a prolonged time period.

2.1.2 Sampling

The purpose of sampling is to select a group that is representative of the population being studied and thus draw conclusions about the population from the sample (Dane, 1990). Sampling designs have been developed to increase the chances of selecting individuals who will be representative of the population (De Poy and Gitlin, 2005), and the extent to which they do so is called the external validity. The first step in sampling is to determine the population (a population being defined as the complete set of elements that share common characteristics). When this has been done the sample can be drawn. Sampling methods are classified into probability and non-probability methods.

Probability sampling processes include random sampling, systematic sampling and stratified sampling. In pure random sampling each member of a population identified has an equal chance of being selected (Bland, 2000). Systematic sampling is performed by selecting every *n*th subject in the population under investigation. In stratified sampling the relevant strata are defined, e.g. gender, age or racial groups and random sampling is used within each stratum to give a sufficient number within each stratum (Ostbye, 1992). It is often used when one or more of the strata contains a small percentage of the overall subjects (Hill and Hill, 1991). Stratified random sampling enhances sample representation and lowers sampling error on a number of predetermined characteristics. Using stratified random sampling one is assured that the sample contains proportionate numbers of each subdivision (Hill and Hill, 1991). After the divisions into these strata, a random selection is taken from each and the same survey is carried out in all.

In non - probability sampling methods, subjects are selected based on other means, including accidental sampling, quota sampling, and purposive sampling. Unlike probability sampling, in non - probability sampling the degree to which the sample differs from the population is

unknown, and therefore sampling error cannot be estimated (De Poy and Gitlin, 2005). The most common method of obtaining a non - probability sample is by convenience (accidental/availability) sampling and selection is based on subject availability. Subjects enter the study until the required number is reached and an example of such would be recruiting consecutive patients from a clinical setting. Non - probability sampling may be used when it is not possible or ethical to select a random sampling method (De Poy and Gitlin, 2005). Purposive sampling (may be called judgemental sampling) refers to procedures where a sample of specific individuals are selected. An example of purposive sampling is that by Reinehr *et al.* (2005) where children who had been referred to obesity centres were studied for cardiovascular risk factors. In exploratory work and pilot projects this method may be useful. Quota sampling is used to obtain proportions of subject types who may be underrepresented by convenience sampling (e.g. by age range or gender) (Polgar and Thomas, 2000). Presumed subdivisions of the population are used as the basis of the selection process.

The number of subjects in a study needs to be of sufficient size so that correct inferences from a sample to a population can be made (Campbell and Machin, 1999). Sampling error is related to sample size, and as sample size increases the probability of sampling error decreases (Polgar and Thomas, 2000). The sample size calculation is based on the number required to test a hypothesis and is related to statistical power. The statistical power of a study is the probability of rejecting the null hypothesis when it is in fact false (Campbell and Machin, 1999). If an intervention is being tested, then sufficient power is required to detect a difference between the experimental and control group. Determining sample size is based on the data analysis procedures to be used, the level of significance (usually 0.05 or 0.01 level), the statistical power (0.80 generally the minimum level acceptable) and the effect size (De

Poy and Gitlin, 2005). If the effect size is small, a large sample size may be necessary to detect differences.

2.1.3 Reliability and validity of measures

(a) Reliability

Reliability refers to the ability of a measure to produce consistent results when administered more than once (Campbell and Machin, 1999). Random errors can affect reliability by producing a bias in the measure due either to transient changes in the respondent, the situation or methodology. To reduce error and improve reliability, standardized techniques are recommended (Stewart *et al.*, 1992).

Test-retest reliability estimates how much confidence one can have in a test over different occasions. To establish test-retest reliability, the test is administered to the same individual(s) twice under the same conditions within a predetermined time interval (Stewart *et al.*, 1992). The time interval selected depends on the characteristics of the sample and the type of test, e.g. in children maturation may affect some measures if the time interval is relatively long. In terms of measuring physical activity there may be real change over a time period. As physical activity is not a stable behaviour, the physical activity measurements from one point in time to another may vary and therefore test-retest reliability can be difficult to establish.

Test-retest reliability is assessed by a correlation coefficient obtained by repeated administrations of a measure and is expressed as a coefficient that ranges from 0 to 1. The lower the error variance the higher the correlation coefficient, such that at 1 no measurement error occurs (Polgar and Thomas, 2000). Even in the best conditions, no test has 100% reliability, and for most research a reliability of 0.8 represents an acceptable estimate (Stewart *et al.*, 1992). The intra-class correlation (ICC) measures the average similarity of

scores performed by two ratings, and, therefore if one examiner is systematically higher than the other, the value will not be one.

Inter - rater reliability refers to the consistency of measures made on one subject by different raters. It involves two or more trained individuals applying the same test, and the degree of reliability is assessed (Stewart *et al.*, 1992). Generally in research there is a limited number of investigators, and, where more than one assessor exists, there is a need to confirm inter-rater reliability prior to data collection. The term for the consistency of one examiner in applying a test is intra-rater reliability (Dane, 1990).

(b) Validity

Validity refers to the extent to which a test measures what it is intended to measure (Campbell and Machin, 1999). Demonstration that a test is valid may be easy where a specific anthropometric measure is required, e.g. height, but can be more difficult when a physical activity measure is the test requiring validation. Validity can be considered under four types:

- content validity,
- construct validity,
- criterion-related validity (concurrent or predictive)
- face validity,

Content validity refers to whether a test incorporates all aspects within the domain being tested (George *et al.*, 2000). An example of content validity when measuring physical activity could be whether all intensities of activity can be measured, e.g. light, moderate and vigorous activity.

Construct validation refers to how well a test measures a theoretical construct which is often quite abstract, e.g. pain or quality of life, and for such validation the use of many data sources may be necessary (Stewart *et al.*, 1992). Construct validity is a process combining a number of indicators of the variable in question (McDowell and Newell, 1996). An example of a construct is physical activity which incorporates type, intensity, frequency and duration. The validity of a questionnaire that measures physical activity would need to be examined in terms of these components.

Criterion related validity refers to the extent to which scores on the test are correlated with some external criterion (George *et al.*, 2000). There are two types of criterion related validity; concurrent and predictive. Concurrent criteria are those outcomes that are seen immediately whereas predictive appear after a period of time (Stewart *et al.*, 1992). An example of concurrent validity would be comparing energy expenditure measured via an accelerometer with that measured by a metabolic cart. An example of predictive validity would be comparing habitual regular activity measured by a specific method with body composition following a number of years.

Face validity refers to whether the target population thinks the instrument measures what it is supposed to measure (Stewart *et al.*, 1992). An example of good face validity would be a weighing scale to measure weight.

In addition to reliability and validity, the sensitivity of a measure to change is also required in research (Polgar and Thomas, 2000). This reflects the ability of a measure to detect small amounts of change.

2.2 Measures of physical activity, body composition and fitness

This section examines the measurement tools that evaluate physical activity, body composition and physical fitness. In the examination of the measurement tools consideration is given to their application in children.

2.2.1 Measurement of physical activity

Physical activity is defined as body movement produced by skeletal muscles which results in energy expenditure (Caspersen, 1985). Measurement of physical activity is particularly difficult as it is a variable with many dimensions, which include type, frequency, duration and intensity. Physical activity is not a stable behaviour, as habitual levels of activity can vary during the day, with different days of the week and different times of the year.

The “gold standard” method of measuring the energy expenditure as a result of physical activity is by the use of doubly labelled water. The technique uses stable isotopes of hydrogen and oxygen, i.e. deuterium (^2H) and oxygen (^{18}O) ingested as water (Schoeller *et al.*, 1986). The rate at which these isotopes are eliminated from the body is determined and the difference between these is the amount of CO_2 produced. Oxygen uptake and therefore energy expenditure are calculated. It is, however, an expensive technique which requires sophisticated equipment and only provides information on total daily/ weekly (i.e. for the time measured) energy expenditure. The technique does assume other potential confounding variables to be constant (e.g. body temperature). It cannot be used to examine the energy expenditure for acute patterns of physical activity, such as the time spent in specific activities or the intensity of specific exercise sessions (Eston *et al.*, 1998).

The following section examines current methods of measuring physical activity that can be used in the field setting. Common measures include observational methods, questionnaires,

heart rate monitoring and motion sensors. The merits and disadvantages of these methods will be outlined below.

Observational studies of levels of physical activity have mainly been used when examining activity levels in children or the activity in workers in specific jobs e.g. nurses in ward situations. Observers are trained to note behavioural information about the types of, frequency of and the time spent in activities. Prepared forms for the recording of activities are usually used, with definitions of the categories that need to be established, for example sitting quietly, sitting with small movements, walking, running etc. Data can be recorded in either paper or video format. The cost of data collection in observation studies may be high due to the need for trained observers, and therefore the number of subjects in studies of this nature is often small. The work involved in both the preparation and carrying out of such studies can be very intensive (Saris *et al.*, 1986).

Advantages of observation studies include the ability to capture the frequency of physical activities, the duration of activities and the length of intervals between activities of varying intensities. Intensity of activity can be estimated. Information on the physical surroundings and environmental factors which may influence physical activity levels can also be obtained (Johns and Ha, 1999), as can the categorisation of activity levels (Chen *et al.*, 2002).

Measures of physical activity used in large scale studies need to be simple and inexpensive. Where time and manpower are limited and/or where numbers to be assessed are large, questionnaires are often used (Treuth *et al.*, 2005). Questionnaires and interviews are frequently the method of collecting data on physical activity in epidemiological studies (Kohl *et al.*, 2000). The procedure of measuring levels of physical activity by questionnaires doesn't alter subjects' activities (as it is measured after the event), and, by using energy

expenditure tables, an estimate of total energy expenditure can be calculated. Limitations to the use of questionnaires for measuring overall physical activity levels are that subjects do not necessarily recall all of their activities, they may overestimate the time spent in activity or its intensity and finally they may give false information (Rowlands *et al.*, 1997). Establishing validity for activity questionnaires is difficult, as in most instances the comparison is made with another measure, such as heart rate monitoring which can also have limitations.

Energy expenditure in regular activity can be measured by questionnaires by using MET values (Ainsworth *et al.*, 1993). Questions have been designed to estimate a value of the energy expended in regular activities each week. The specific activities participated in over a period of time can be determined. For each activity the number of months that the activity is performed over the year, the average number of days per week of the activity and the average minutes per day of the activity can be determined. The Compendium of Physical Activities classifies the energy costs of human physical activities (Ainsworth *et al.*, 1993), and this can be used to calculate energy expended in regular activity.

Heart rate is an objective, but an indirect, method of measuring physical activity (Eston *et al.*, 1998). The use of heart rate data in quantifying physical activity is based on the linear relationship between heart rate and oxygen uptake, so the relative stress placed on the cardiopulmonary system due to physical activity is assessed. The development of reliable heart rate recorders, that are small in size and weight, has permitted the measurement of activity levels over long time periods. The volume of physical activity (frequency, duration and intensity) can be estimated from continuous heart rate monitoring, and monitors can store information for a number of days (e.g. Logan *et al.* (2000) measured heart rate over 3 days in 3-4 year old children). When the data are downloaded, via an interface onto a computer, heart

rates above a percentage of the maximum can be readily identified and the time spent at specific heart rates obtained.

Heart rate monitoring has been used in many studies assessing physical activity in children (Falgairette *et al.*, 1996; Van den Berg-Emons *et al.*, 1996; Coleman *et al.*, 1997; Janz *et al.*, 1992) and adults (Wareham *et al.*, 1997). Limitations of using heart rate to measure physical activity are:

1. Other factors can increase heart rate such, as emotional stress, temperature and humidity, independent of any change in oxygen uptake (Saris, 1986),
2. Heart rate is a measure of cardiovascular function rather than locomotor activity, and therefore, after exercise, the return to baseline occurs many minutes after activity has ceased. It may therefore overestimate the time spent in activity (Saris, 1986),
3. The type of work performed can affect the heart rate response as upper body work elicits higher heart rates compared to work of the same oxygen cost performed by the lower limbs (Mass *et al.*, 1989).
4. The definition of resting heart rate and its method of determination has an impact on the apparent level of activity (Sleap and Tolfrey, 2001). Ideally, individual fitness should be measured prior to the determination of specific heart rates for intensities of activity. This makes it difficult to measure activity in large cohorts.

Motion sensors have evolved from mechanical devices, such as simple pedometers, to electronic accelerometers which reflect not only the occurrence of body movement but also the intensity of movement. Pedometers record acceleration and deceleration of the waist in the vertical direction but do not record the intensity related to different speeds of walking or running. For large studies, where total activity is of interest, the pedometer may be useful.

However, despite the ability of pedometers to differentiate between various levels of occupational activity (Sequeia *et al.*, 1995) they cannot determine intensity of activity.

The assessment of physical activity by accelerometry is based on the measurement of body movement or the dynamic component of activity. Accelerometers are designed to measure physical movement without impeding activity in free-living situations and can measure periods of inactivity as well as the quantity and intensity of movement (Puyau *et al.*, 2002). The ability of newer accelerometers to store data over a number of weeks permits measurement of habitual activity. The accelerometer may be uni-axial or tri-axial. Uni-axial accelerometers can only measure movement in one plane (vertical) whereas tri-axial accelerometers can measure movement in the sagittal, horizontal and vertical planes.

While the reliability and validity of uni-axial accelerometers in measuring activity has been demonstrated, a limitation is that movement in only one direction can be captured. Tri-axial accelerometers measure activity in the three planes.

Other more recent activity monitors include the BioTrainer Pro and the SenseWear Armband (King *et al.*, 2004). The former is a biaxial accelerometer that can sample data between 15 seconds and 5 minute intervals and can store up to 112 days of data. The SenseWear Armband is a biaxial accelerometer and also a heart rate receiver and thermocoupler which can measure heat production. The monitor is a wireless armband and is worn in contact with the upper arm skin surface.

2.2.2 Measures of physical activity specifically used in children

In very young children observation may be the most suitable method of measuring activity. The logistics of conducting observational studies in children are such that data may need to

be collected during school break times, lunch times and physical education classes and during free time outside school.

The use of questionnaires with children requires specific considerations. Below the age of 10-12 years, children may only be able to give limited information about their activity patterns. An estimate can be provided by parents, teachers or other adults, but obviously this information may need to be estimated for outside activities. Questionnaires designed for adults are usually not suitable for children because of the differences in the activity patterns of adults and children (Bailey *et al.*, 1995). Much activity in young children is spontaneous and non-organised which therefore cannot be classified easily. Recall of activities by children can be inaccurate (Baranowski, 1988), and Wallace *et al.* (1985) reported that 11-13 year olds recalled only 40% of their activities during the previous 7 days and 55-65% during the past 24 hours. Generally children have difficulties estimating the duration of activities and time frames may need to be provided for the child. These timeframes could be “on the way to school, break time, way home from school, before dinner” etc. Questions about participation in Physical Education (PE), the number of PE sessions per week, organised sports, transportation to and from school, recreational activities after school or during weekends, may be included to gain information on children’s overall activity levels. A list of activities may need to be provided to aid recall.

The validity of uni-axial accelerometers for the measurement of activity in children has been established (Puyau *et al.*, 2002; Janz, 1994), and accelerometers have been found to be valid in quantifying treadmill walking and running in children (ICC=0.87) (Trost *et al.*, 1998). Theoretically, the three dimensional nature of a tri-axial accelerometer would make it better suited to assess more sporadic lifestyle activities seen particularly in young children. The

validity and reliability of the Tritrac-R3D (a tri-axial accelerometer) was established in young adults (Nichols *et al.*, 1999; King *et al.*, 2004) and both the Tritrac-R3D and RT3 have been validated in boys (Rowlands *et al.*, 2004) in the measurement of treadmill walking and running. Tri-axial accelerometers have been used in a number of recent studies investigating activity in children (Andersen *et al.*, 2006; Hansen *et al.*, 2005; Ruiz *et al.*, 2006; Ekelund *et al.*, 2004). The ability to measure different intensities of activity is of particular benefit. In children, so much activity is spontaneous and therefore difficult to capture with questionnaires (Saris *et al.*, 1986) but such activity can be easily measured by accelerometers. Water based activities cannot be measured by accelerometers.

2.2.3 Measurement of body composition

There are many field and laboratory/clinical techniques available to measure components of body composition. Methods to measure body composition that can be used in primary care and in field settings include skin-fold thickness measurements, body mass index and waist circumference. Skin-fold thickness provide data on the size of subcutaneous fat. While intra-observer error may be low generally it may be more difficult to obtain precise measures in subjects with excess body fat due to the bulk involved. In children with obesity the validity of skin-fold thickness has been found to be low (Semiz *et al.*, 2006).

Body mass index is calculated as weight in kg divided by height in meters squared. BMI is a useful and convenient measure, but a limitation is that it does not distinguish weight from fat compared to weight from muscle. Athletes such as rugby players, may have a high BMI but a low percentage of body fat. In addition, BMI does not give information on the distribution of body fat which has important clinical consequences. Individuals with excess fat around the abdomen (apple shaped) are more likely than those with fat stored around the hips (pear shaped) to have adverse health consequences (Tanne *et al.*, 2005; Larrson *et al.*, 1984). As

the pattern of fat distribution is important in terms of cardiovascular mortality and morbidity (Katzmarzyk and Craig, 2006), it is important to obtain valid measures of this distribution.

Waist circumference provides a measure of central fatness and is a frequently used measure that is easily done in both a clinical and field environment. In adults and children, waist circumference is associated with insulin resistance and metabolic risk factors (Esmailzadeh *et al.*, 2006). Waist circumference is also determined by gender, age and body shape, and such factors need to be considered in interpreting measures, and there is a need for health related thresholds in relation to BMI (Ardern *et al.*, 2004). Reliability of the measurement of body circumferences have been found to be significantly higher than skin-fold thickness (Mueller and Malina, 1987).

A number of laboratory methods divide body mass into fat mass (FM) and fat free mass (FFM) and thus avoid the problems of both components of weight that occur with measures such as BMI. There are varying amounts of reference data for such measures in children (Wells and Fewtrell, 2006), but the main limitation to widespread use of these techniques is their availability outside clinical facilities. Sophisticated technologies, such as dual-energy x-ray absorptiometry measure body composition from the differential absorption of x-rays (Wells and Fewtrell, 2006). Magnetic resonance imaging (MRI) distinguishes between adipose and non-adipose tissue. The hydrostatic weighing technique uses Archimedes's principle that a body immersed in fluid is acted upon by a force equal to the mass of the fluid displaced. Residual lung volume is measured by spirometry and the body volume is calculated as the difference in body weight measured by air-displacement technique and the measure obtained by underwater weighing. The value is then corrected for the residual lung volume (Wang *et al.*, 2006). Hydrometry (isotope dilution) can be used to measure total body water (TBW) which permits an estimation of FFM. In this method a dose of water labelled

with deuterium is given and fluid samples are analysed by isotope ratio mass spectrometry.

Bioelectrical impedance analysis (BIA) is a relatively new technique used for the estimation of body composition. It is a non-invasive method which is based on the principle that biological tissues act as conductors or insulators and the flow of current through the body follows the path of least resistance. Adjusting the data obtained for height allows an estimation of TBW which can then be converted to FFM (Wells and Fewtrell, 2006).

2.2.4 Measures of body composition in children

BMI can be transferred to SD (standard deviation) scores (British Growth References, 1995) and expressed as z scores (Cole *et al.*, 1998)(see also Chapter 5, [page 131](#)). In children and those younger than 18 years, BMI is not a stable measurement and varies from birth to adulthood. Cole *et al.* (2000) published data standardised for age and gender based on the international cut- off points for BMI for overweight and obesity in children, and these are used as the definitions. BMI has been recommended for use in assessing children and adolescents aged 2-20 years (Cole *et al.*, 2000) and provides a reasonably reliable screening tool that is easy to use on large populations. There is some controversy about absolute cut-off points with countries using between the 85th and 97th percentile as cut off limits (Guillaume, 1999). These differences in cut off points would result in very different estimates of obesity prevalence.

The validity of waist circumference as a measure of central fat was investigated by Taylor *et al.* (2000). Trunk fat mass was measured by dual – energy X-ray absorptiometry in 278 girls and 302 boys aged 3-19 years. The 80th percentile for waist circumference correctly identified

89% of girls and 87% of boys with high trunk fat mass, leading the authors to conclude that waist circumference provides an effective measure of truncal adiposity.

2.2.5 Measurement of physical fitness

Physical fitness may be defined in terms of cardiovascular capacity, muscular strength and endurance and the flexibility of muscles and joints. This section concentrates on cardiorespiratory capacity and this term will be used inter-changeably with the term physical fitness as explained in Chapter 1, section 1.3, where many of the studies discussed have employed the terms on a similar basis. The “gold standard” criterion of cardiovascular capacity is maximal oxygen uptake ($\text{VO}_2 \text{ max}$). $\text{VO}_2 \text{ max}$ is defined as the maximal volume of oxygen the body musculature can take up and use (Armstrong and Welsman, 2000). $\text{VO}_2 \text{ max}$ is usually expressed in one of 2 ways: in absolute terms, as litres per minute (liters/min) or relative to an individual's body mass in millilitres per kilogram per minute (ml/kg/min) (Mc Ardle *et al.*, 1996). The most accurate assessment of $\text{VO}_2 \text{ max}$ is by the measurement of expired air composition and ventilatory volume during maximal exertion (Haskell *et al.*, 1992).

The measurement of $\text{VO}_2 \text{ max}$ involves open circuit spirometry, where the subject breathes through a valve with the nose occluded, while pulmonary ventilation and expired O_2 and CO_2 are measured. Measurable workloads are imposed while monitoring ventilation per minute (minute ventilation), O_2 consumption, CO_2 production, heart rate, blood pressure, oxygen saturation and heart rate. Directly measuring VO_2 in such a manner requires considerable resources, including equipment and space. It is therefore mainly confined to research purposes or to the diagnosis of patients with suspected cardiovascular or pulmonary conditions. Trained personnel are also required to conduct the test and to ensure the safety of the participant at all times.

If measurement of VO_2 was confined to the laboratory, only limited numbers of subjects could be tested. As a result, field tests have been devised where a number of subjects can be tested at the same time and little equipment is needed. Field tests often consist of walking or running a distance in a given time e.g. six-minute walk test (American Thoracic Society, 2002), the 1.5 mile walk/run test (Mc Naughton *et al.*, 1998) or stepping within a specified time (Balfour –Lynn *et al.*, 1998).

A test used in the assessment of exercise tolerance that can be performed outside of an exercise laboratory is the physical work capacity at a heart rate of 170 bpm (PWC 170) (Boreham *et al.*, 1990). The test is performed on a cycle ergometer and requires that the child pedals continuously at 60 revs/min usually for 6 minutes and during this time workload is increased twice. Heart rate (usually measured by telemetry) over the last 5 seconds of each stage is used to gauge the increase in load. The workload corresponding to the heart rate of 170 beats per minute is determined. A test that does not require gas analysis is the 20 MST which was originally developed by Leger and Lambert (1982) and consists of incremental stages of running back and forward between two markers set 20 meters apart, with the pace set by bleeps from a cassette tape. The initial velocity is 8.5 km/hr and increases by 0.5 km/hr every minute. The test is terminated when the subject cannot reach the end lines concurrent with the audio signals on 2 consecutive occasions. The last stage number achieved in the test is used to predict maximal oxygen uptake from the speed of the stage and the age of the child (for equation to calculate $\text{VO}_{2 \text{ max}}$ see appendix 1).

Boreham *et al.* (1990) compared the 20-MST and the PWC170 in adolescents (24 boys and 24 girls) with $\text{VO}_{2 \text{ max}}$ in the laboratory and found similar powers of prediction for both field tests (PWC170 vs $\text{VO}_{2 \text{ max}}$, $r=0.84$; 20 MST vs $\text{VO}_{2 \text{ max}}$ $r=0.87$). However, the authors

acknowledged the ease of use of the 20-MST compared to the PWC 170 in the field setting. With the 20-MST a number of subjects can be tested together and it is therefore suitable for use in school or club situations.

2.2.6 Measures of physical fitness used in children

The 20 - MST has been used in many studies assessing aerobic capacity in schoolchildren (Boreham *et al.*, 1993; Leger *et al.*, 1988; Tomkinson *et al.*, 2003; Guerra *et al.*, 2002) and has been found to be a valid predictor of $\text{VO}_{2 \text{ max}}$ in adolescent children (Boreham *et al.*, 1990). The test simply requires space, field markers and an audiocassette player. Mc Naughton *et al.* (1996) investigated the relationship between the 20 - MST (as described above) and directly measured VO_2 in the laboratory in children aged 12-16 years and found a correlation between the two measures of $r=0.87$ ($P < 0.001$). Other workers have also investigated the relationship between directly measured $\text{VO}_{2 \text{ max}}$ and the shuttle running test in children. Van Mechelen *et al.* (1986) found a correlation of $r=0.76$ between laboratory measured $\text{VO}_{2 \text{ max}}$ and the 20 MST in children, and Boreham *et al.* (1990) found a correlation of $r=0.87$ when the test was correlated with directly measured $\text{VO}_{2 \text{ max}}$ in 24 adolescent girls and 24 adolescent boys and concluded that the test was a valid predictor of $\text{VO}_2 \text{ max}$ in adolescent children. In 12 year old children the 20-MST was found to be a reliable measure of CRF ($r=0.83$ boys and $r=0.76$ girls, $P < 0.03$) and was consistent in test retest reliability ($r=0.73$ boys, $r=0.88$ girls, $P < 0.01$) (Mahoney, 1992).

2.3 Data analysis- general principles

In terms of analysing data there are a number of methods that need to be considered. Data organisation includes frequency distributions and permits graphing by histograms and polygons. Graphing the data permits the visualisation of trends. Measures of central tendency include medians, modes and means, and measures of dispersal include the range, variance and standard deviation. Standard normal distribution is illustrated by a normal curve which is symmetrical about the mean.

Where a relationship between two variables is required, correlation coefficients are used. In studies examining reliability and validity of measures, correlation coefficients are frequently used. Correlation coefficients include the Pearson r correlation coefficient, the Spearman ρ correlation coefficients and the intra-class correlation. Pearson's r is a measure by which paired scores are correlated. Spearman's correlation is used with ordinal level data has, and is based on rank-ordering of the scores obtained. The intra-class correlation (ICC) measures the average similarity of scores performed by two ratings/raters, and therefore if one examiner is systematically higher than the other the value will not be one. The process of comparing a new method of specific measurement to an established measure can be done by calculating a correlation coefficient. Bland and Altman (1986) claim this to be inappropriate as a correlation measures the strength between the two measures rather than the agreement between the two. A perfect correlation (i.e. $r=1$) between the two measures would be evident if the points lay on a straight line, and therefore, even when the agreements between the measures may be poor, the correlation could be close to 1. The Bland and Altman method plots the differences between the methods against their mean and the bias is estimated by the mean difference and the standard deviation of the differences. If the limits of agreement are small enough then there can be confidence in the new measure and assurance that it can be

used in place of the measure it was compared to. This also says how far the two measures are apart in the units being measured.

Inferential statistics are used for drawing generalisations from the sample statistics to the population in question. Even when random sampling is used, there is always a chance of sampling error, and the principles of inferential statistics are used to calculate the probability of error (Bland, 2000). Confidence intervals represent a range of scores which contains the true population mean at specified levels of probability and the common one used are the 95% confidence intervals (Hill and Hill, 1991). Hypothesis testing is the process of determining statistically if the findings of a study are real effects or are due to chance. The procedures used are based on probability theory, and the statistical test is a procedure for investigating if the differences demonstrated are real rather than due to random sampling error. It is generally regarded that a probability of 1 in 20 is the borderline between significant and non – significant, and this is termed $P < 0.05$ (Campbell and Machin 1999). Regression analysis is used when there is a requirement to predict change in one variable due to a change in another (Bland, 2000).

CHAPTER 3: EVALUATION OF PHYSICAL ACTIVITY IN DUBLIN CHILDREN AGED 7-9 YEARS (STUDY ONE)

3.1 Introduction

The literature in the area of the health benefits of physical activity in children has been explored in Chapter 1. There are four studies that have investigated activity levels in Irish children. A 1989 study of fitness and activity levels in 10-13 year-old Irish children revealed that one third of the sample exercised four or more times per week (Watson and Drummy, 1993) and only 23% walked or cycled to school. The SLAN study of 1998 examined 9-17 year old Irish children and found that 53% exercised 4 or more times per week (SLAN, 1999). Boys exercised more than girls and in both genders exercise participation decreased with age. The physical activity of 11-12 year olds in 62 National schools was studied by interview by Sullivan (2002). Boys were doing significantly more recreational activity than girls ($P < 0.001$). The predictors of physical activity level were found to be PE ($P < 0.001$), gender ($P < 0.001$), membership of a sports club ($P < 0.001$), and social integration status ($P < 0.001$). In younger children (4-5 years) in rural areas, Kelly *et al.* (2005) studied physical activity levels objectively and found significant differences between the genders in time sedentary ($P = 0.0011$), and in moderate to vigorous physical activity ($P = 0.0175$).

There are few published reports on physical activity in Irish children under 9 years of age which involved large numbers (that by Kelly *et al.* (2005) consisted of 41 subjects). As discussed in Chapter 1, the introduction, there are many factors that may need to be considered when studying activity levels in children such as age, gender, social class and environmental issues. Although the central theme of this thesis is the relationship between body composition and physical activity in 7-9 year old children the starting point of this research is the establishment of current activity levels in a large sample of 7-9 year old

children. This study aims to determine physical activity levels in 7-9 year old children in Dublin National Schools. This study has been published in the British Journal of Sports Medicine, Hussey, J., Gormley, J., Bell, C. (2001). *Physical activity in children aged 7-9 years. British Journal of Sports Medicine*, 35, 268-273 (see appendix 7).

3.2. Objectives and research design

The aim of this study was to determine physical activity levels in 7-9 year old children in Dublin National Schools. In addition to surveying parents about their childrens' activity levels, teachers were questioned about resources available for physical education.

The objectives of this study were:

- To determine the amount of energy expenditure in physical activity (duration, frequency and number of activities) that children participate in
- To determine the number of children meeting current (Strong *et al.*, 2005) and previous (ACSM, 1988) physical activity recommendations
- To determine the amount of time spent in sedentary activities
- To determine any gender differences in levels of physical activity
- To determine any differences in physical activity throughout the calendar year
- To determine any differences in levels of physical activity between socio-economic groupings
- To determine the time and facilities for Physical Education in schools

The design selected for the purpose of this study was a cross-sectional survey. The overall aim was to establish physical activity levels in a representative sample of the population and to determine the number of subjects reaching the recommended levels. It did not attempt to

determine the reasons for the activity levels found. It could be argued that a longitudinal study would have been more suitable, but time limitations would not permit the execution of such a study. As a large, geographically representative, sample was to be investigated (see Chapter 2, sampling section, pages 73-74) a questionnaire was the method of choice.

3.3 Methodology

3.3.1 Sampling and subjects

A sample of 7-9 year old children representative of all socioeconomic areas was required for the study, therefore proportional representation from all areas was required. Dublin is divided into five different areas of deprivation index where 1 is the highest (socio-economically) and 5 is the most deprived (Small Area Health Research Unit (SAHRU)). The indicators that SAHRU use to define the level of deprivation are: unemployment, low social class, no car, rented accommodation and overcrowding.

The procedure involved in obtaining the sample was as follows. A list of National primary schools in Dublin (which included Co. Dublin as well as Dublin City) was obtained from the Department of Education and Science. The schools were listed according to postal code and consisted of 396 schools suitable for inclusion (excluding schools for children with special needs). The schools were then coded by deprivation index into the 5 areas (SAHRU Technical report, 1997). This was done by mapping the area where each school was into its specific DED area code.

As 10% of schools were to be sampled, every 10th school (systematic sampling) within each area of deprivation index- DED (Deprivation index – Electoral Division) was selected (to ensure geographical spread from each DED). The primary sampling unit was the school, and within each school the teachers/parents of second classes were surveyed. There were 396

schools listed and the aim was to obtain participation of 39 schools i.e. 10% of the sample. Such a method was a combination of stratified and systematic sampling. The list of schools within each stratum was geographically listed and therefore such a method ensured socio-economic and geographic representation.

The principal of each selected school was contacted and the aim of the study was explained. As the age of interest was 7-9 year old children, it was second class children who were targeted.

3.3.2 Measures

Questionnaires measuring physical activity differ with respect to the age they are suited to, the types and intensities of activities they assess and the timeframe over which they measure activity. At the time of this study (1999) the questionnaire that was more appropriate in terms of the objectives was the Modifiable Activity Questionnaire for Adolescents (MAQA) ((Aaron *et al.*, 1993) (see Appendix 2)). The MAQA can measure time spent in hard and light activity over the previous two weeks and the questionnaire assesses physical activity over the previous year (Aaron *et al.*, 1993). It includes questions on the number of times in the previous 14 days the subject engaged in at least 20 minutes of hard and of light exercise. Hours per days spent watching television, videos, playing computer games and the number of competitive activities the adolescent participates in is assessed, as is the energy expended in regular physical activity each week.

The reproducibility and validity of the original questionnaire was established by Aaron *et al.* (1995). The reliability of the questionnaire was investigated in 100 high school students by means of an initial test, another one month later and a final one year later. Reliability was examined over one month and one year with repeated questionnaires and was higher over one

month ($r=0.79$) than one year ($r=0.66$). Validity was examined by comparing the questionnaire to four 7 day recalls of activity and significant correlations were found for both genders and different age categories (all $P<0.01$).

As the children in this study were younger than adolescents (the age group that the questionnaire was originally designed for) it was thought that parents would provide more reliable and accurate information in terms of time spent in activities. In the original questionnaire the first question sought information on the amount of times in the previous 2 weeks that the child had participated in at least 20 minutes of hard exercise, with hard exercise defined as “exercise that made the child breathe heavily and their heart beat fast” (see Appendix 2). Information on the amount of times in the previous 2 weeks that the child had participated in at least 20 minutes of light exercise was sought in the second question. Light exercise was defined as exercise that did not make the child breathe heavily or their heart beat fast. The third and fourth questions dealt with the number of hours per day that the child spent watching television, videos or playing computer games and the number of competitive activities the child participated in.

The final question sought to estimate a value of the energy expended in regular activities each week. The parent marked the activities the child participated in regularly over the last year. For each activity the number of months that the activity was performed over the year, the average number of days per week of the activity and the average minutes per day of the activity were ascertained. Using the above information a value for the hours per week spent at each activity was calculated. The method of calculation is shown at the end of the Questionnaire in and is also found below.

The modifications to the original questionnaire included the addition of a question on mode of transport to school and, as these children were under 9 years of age, the question on

involvement in competitive activities was removed. Under the past year regular activities question, sports played in Ireland, such as Gaelic football, hurling and rugby, were added (see Appendix 3 for modified version). The Compendium of Physical Activities classifies the energy costs of human physical activities (Ainsworth *et al.*, 1993), and this was used to calculate energy expended in regular activity

The results of this study were compared to three sets of guidelines (ACSM, 1998; ACSM, 1988; Strong *et al.*, 2005), and the minimal MET for overall energy expenditure in activity were calculated by the following:

1. **Recommendation one:** At the time of the study (1999-2000) the general activity recommendations were: “30 minutes of moderate activity on most and preferably all days of the week”. In order to decide a threshold for minimal MET/hr/wk in terms of a child participating in 30 minutes per day for 4 days of the week (most days) at a moderate intensity (i.e. 4 METs)

Minimal MET/hr/wk

$$\begin{aligned}
 &= \frac{(\text{No of months of activity}) \times (\text{weeks per month}) \times (\text{days per week}) \times (\text{mins per day})}{\text{mins per hour} \times \text{weeks per year}} \times 4\text{METs} \\
 &= \frac{12 \times 4.3 \times 4 \times 30}{60 \times 52} \times 4\text{ METs} \\
 &= 2 \times 4\text{ METs} \\
 &= 8\text{ MET/hr/wk.}
 \end{aligned}$$

2. **Recommendation two:** The ACSM (1988) guidelines specifically for young people were that young people should engage in “20-30 minutes of vigorous exercise every day.” The calculation of minimal MET value was as follows.

$$= \frac{12 \times 4.3 \times 7 \times 20}{60 \times 52} \times 6 \text{ METs (As the activity is vigorous the value is 6 MET)}$$

$$= 12 \text{ MET-hr/wk.}$$

3. **Recommendation three:** In 2005 the guidelines changed to the following: “school-aged youth should participate in 60 minutes or more of moderate to vigorous physical activity that is developmentally appropriate, enjoyable, and involves a variety of activities.” (Strong *et al.*, 2005).

The calculation of minimal MET value was as follows.

$$= \frac{12 \times 4.3 \times 7 \times 60}{60 \times 52} \times 4 \text{ METs}$$

$$= 28 \text{ MET/hr/wk.}$$

3.3.3 Study procedure

Prior to their agreement to participate a copy of the questionnaire (see below) and a letter of explanation were sent to each principal. If a school principal declined to participate in the study the next school on the list within the same area was selected. Following consent from the school, questionnaires and consent forms for parents were delivered to the school along with a letter of explanation for the parents. A different questionnaire was sent to teachers of the children in second class in the schools participating. The questionnaire to teachers contained questions on the frequency, duration and location of Physical Education classes during school hours.

3.3.4 Data analysis

Data were coded and entered into Excel (Microsoft). Descriptive analyses were performed and data were presented graphically. Summary statistics (means $\pm$ standard deviations) and

frequency distributions were the most appropriate for descriptive purposes. Data were entered into SPSS (version 12). Chi – squared tests were used for comparison of categorical variables between genders. The percentage of children meeting the three different guidelines was calculated and a single sample proportion test and an independent sample proportion test were performed on the percentages. Normality of the MET/hr/week data was investigated, and t-tests (unpaired) were used for comparing differences between genders for MET/hr/wk, and for comparing the energy expended in regular activity (MET/hr/wk) in children from deprivation areas 1 compared to 4 and 5. Significance was set at $P < 0.05$. The normality of the data for MET/hr/week was investigated and log transformed if required. Regression analysis was performed to investigate the differences in energy expended in regular activity controlling for gender and DED area. The energy expenditure in regular activity in subjects in DED 1 was compared with the other four areas.

3.4 Results

3.4.1 Return rates

Thirty-seven schools participated in the study. Average return rates from each school ranged from 38% in deprivation area 5 to 53% in deprivation area 1 (see Table 3.1). The total number of schools in each deprivation area was different and therefore the number of schools in each area suitable for participation varied (e.g. there were 16 schools in area 1 participating compared to 2 schools in area 3). In addition, even when a school principal agreed for his/her school to participate, the number of questionnaires returned compared to those distributed varied across schools and areas. In the third row in Table 3.1 the return rates that are presented are the means that were returned from the total number of questionnaires distributed to the schools in each area. As the number of children in second class in each school varied it was deemed more appropriate to give the percentage that returned rather than the actual numbers.

Seven hundred and eighty six questionnaires were analysed. Of the 786 subjects, 352 (45%) were boys and 434 (55%) were girls. Eighty-six subjects (11%) had a medical condition that could interfere with physical activity (74 subjects had asthma).

Table 3.1: Return rates from schools, subject numbers and mean MET/hr/wk

Area	1	2	3	4	5	Total
Number of schools that participated	16	8	2	8	3	37
Mean return rate	53%	41%	42%	48%	38%	
Range	14%-94%	16%-91%	40%-45%	23%-93%	27%-60%	
Number of subjects who completed the survey	473	157	45	82	29	786
Mean MET/hr/wk	36	40	40	42	70	39

3.4.2 Time in hard and light exercise

Thirty nine percent of children participated in at least 20 minutes of hard exercise, 3 or more times per week ($\geq 6-8$ times in 14 days) and significantly more boys (53%) than girls (28%) contributed to this result ($P<0.001$) (see Figure 3.1a). As can be seen in Figure 3.1a there were significantly more girls engaging in 20 minutes of hard exercise on no occasions or 1-2 times per week. There were significantly more boys than girls who engaged in 20 minutes of hard exercise 12-14 times per week. There were no significant gender differences in the participation in light exercise with 57% of children exercising lightly for at least 20 minutes 3 or more times per week (see Figure 3.1b).

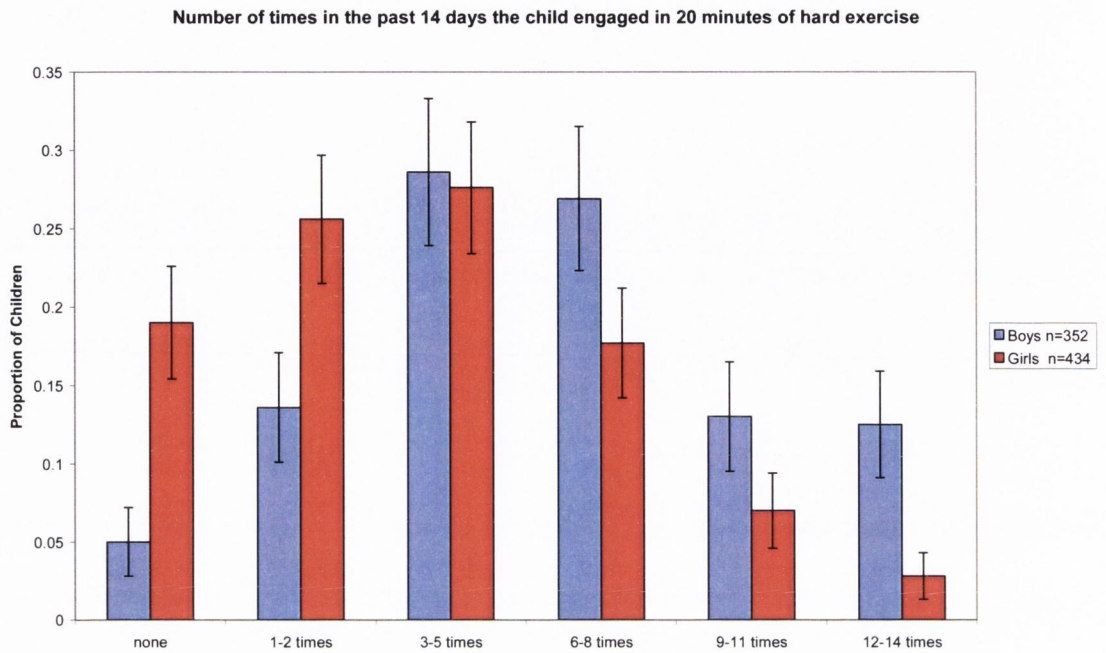


Figure 3.1a: Number of times in the past 14 days (with 95% C.I.s) the child engaged in at least 20 minutes of hard exercise.

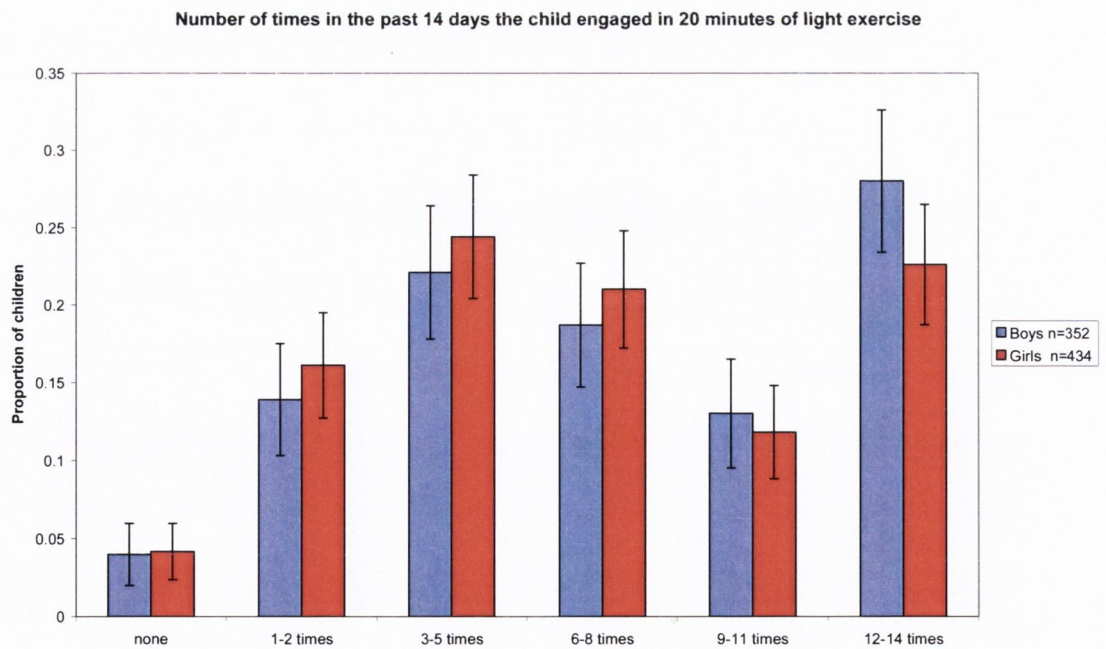


Figure 3.1b: Number of times in the last 14 days (with 95% C.I. s) the child engaged in at least 20 minutes of light exercise.

3.4.3 Transport to school

An examination of the mode of transport to school revealed that 40% of children (44% boys, 37% girls) walked to school and 33% (31% boys, 35% girls) were brought to school by car. Twenty two percent (21% boys, 29% girls) had a combination of walking and being driven to school and 5% of children travelled by bus (see Figure 3.2a). Thirty five percent of children in deprivation index area 1 walked to school compared to 66 percent in areas 4 and 5 (see Figure 3.2b).

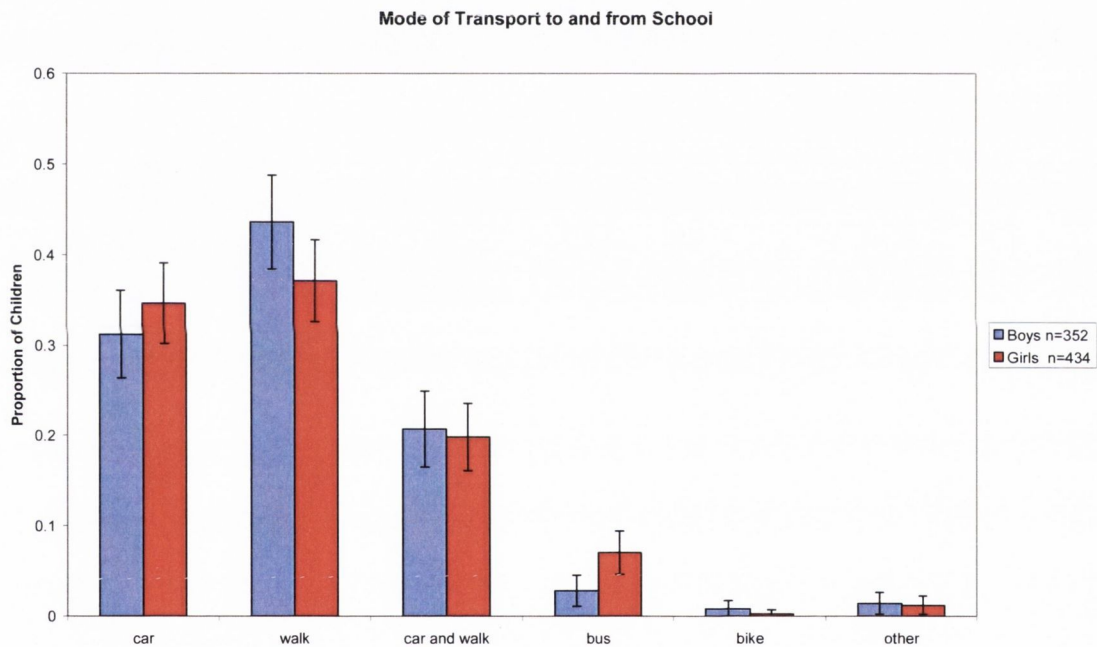


Figure 3.2 a Proportion of children (with 95% C.I. s) using various modes of transport to school.

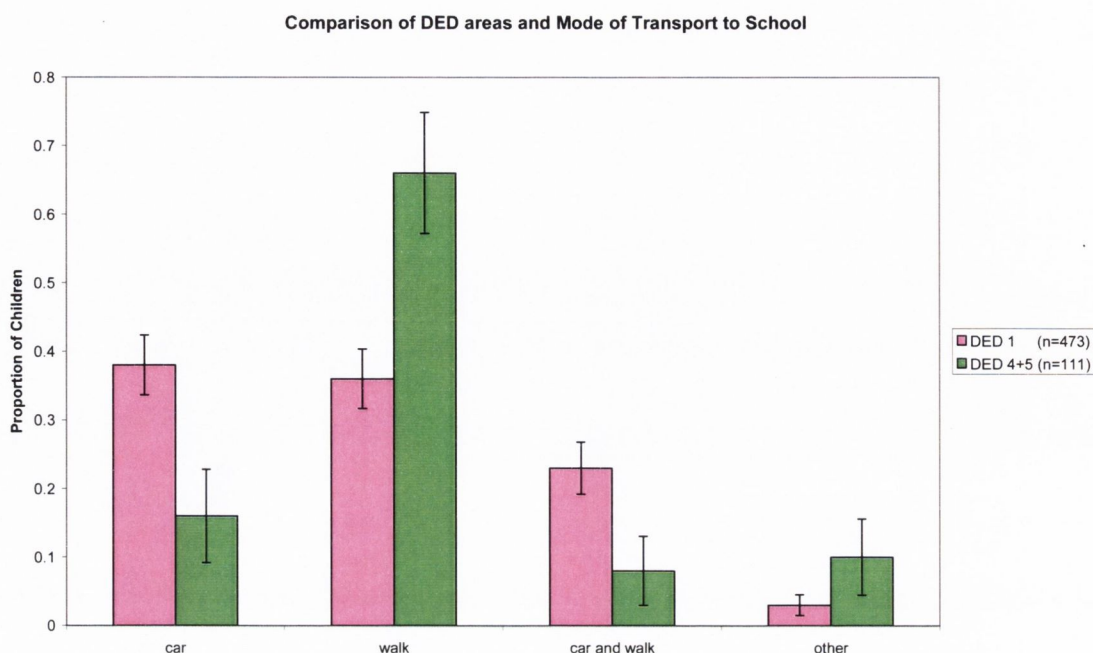


Figure 3.2 b: Comparison of mode of transport to school: Proportion of children (with 95% C.I. s) in area of deprivation 1 compared to the proportion of children in areas of deprivation 4-5

As can be seen in Figure 3.2 b there were significantly more children from DED 1 who were brought to school by car when compared to DED 4 and 5. In terms of walking to school there were significantly more children from DED 4 and 5 who walked to school compared to those in DED 1.

3.4.4 Time in front of a television/PC screen

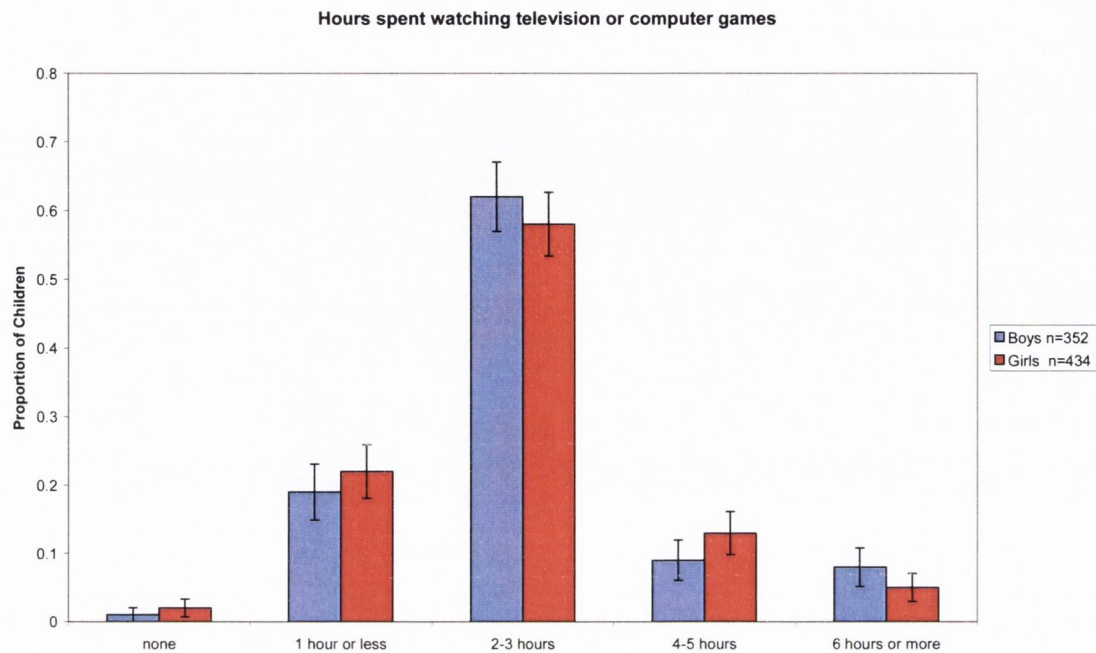


Figure 3.3 a: Proportion of children (with 95% C.I. s) watching TV/video or playing PC games

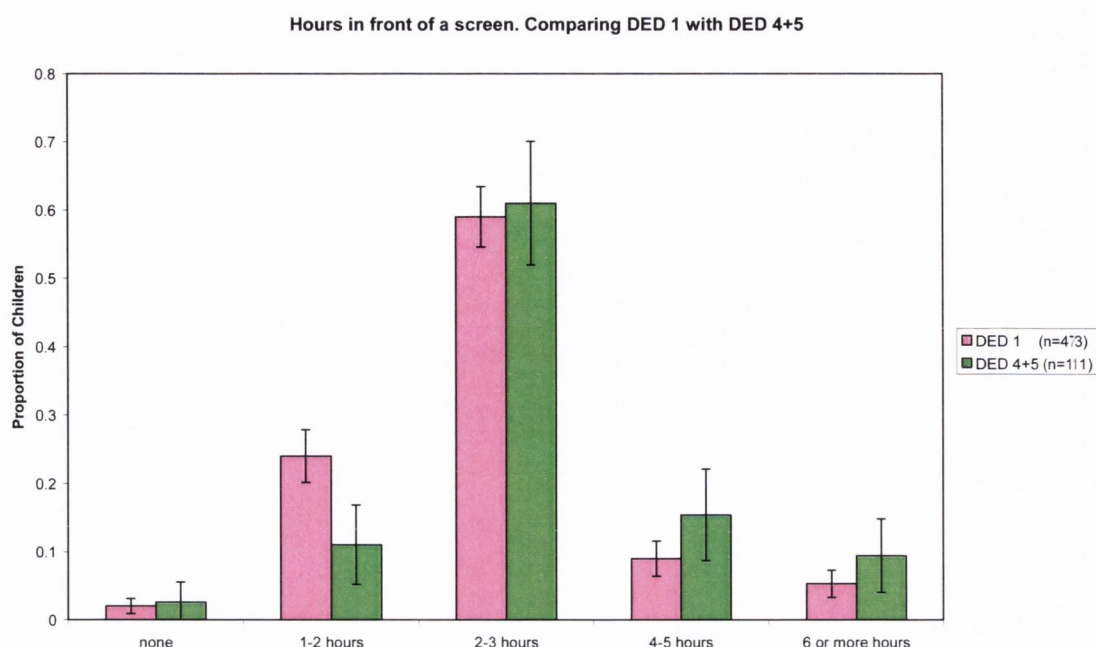


Figure 3.3 b. Comparison of Total hours spent watching TV/video/playing PC games. Proportion of children (with 95% C.I.s) in area of deprivation 1 compared to the proportion of children in areas of deprivation 4-5

Sixty percent of children were spending up to 3 hours per day in front of a screen and 18% were spending more than 3 hours per day. No gender differences were seen (see Table 3.3 a). No differences in the number of hours spent watching TV/videos/playing PC games were seen when area 1 was compared to areas 4 and 5 (see Table 3.3 b).

3.4.5 Energy expenditure in regular physical activity and percentage of children meeting activity recommendations

Overall, boys were expending significantly more energy in participating in regular activities than girls (boys 46 MET/hr/wk $\pm$ 41.9 compared to girls 33 MET/hr/wk $\pm$ 30.8) ($P < 0.001$).

Recommendation 1: When 8 MET/hr/wk was used as a minimal level of regular activity participation the number of subjects falling beneath this activity threshold was calculated.

Four percent of boys ($z=17.1$, $P<0.001$) and 12% of girls ($z=16.08$, $P<0.001$) were reported to engage in less than the minimal recommendation. The difference between the two proportions was significant ($z= 3.45$, $P= 0.006$).

Recommendation 2: In terms of the recommendation of 20 minutes of vigorous activity every day 12 MET/hr/week was calculated as that required. It was found that 11% of boys ($z=14.76$, $P<0.001$) and 19% of girls ($z=12.72$, $P<0.001$) were not achieving this level. The difference between the proportions was significant ($z=3.32$, $P=0.001$).

Recommendation 3: In terms of the recommendations of Strong *et al.* (2005), 60 minutes of moderate to vigorous physical activity every day, a MET level of 28 MET/hr/week, it was found that 41% of boys ($z=3.46$, $P=0.006$) and 58% of girls ($z=3.31$, $P=0.001$) were not meeting the recommendation. The difference between the proportions was significant ($z=4.79$, $P<0.001$).

The effect of DED on MET/hr/week was investigated by regression analysis (see Table 3.2)). Prior to such the distribution of MET/hr/week was analysed and found not to be normally distributed. When this was log transformed it was normally distributed (see appendices) and therefore the log transformed MET/hr/week was used in the regression analysis.

In addition to the above, a t-test was done comparing the MET/hr/week in subjects in deprivation index areas 4 and 5 to those in area 1 (4 and 5 were combined as the numbers in these areas were small). Children in areas 4 and 5 had significantly higher energy expenditure in regular activity than children in area 1 (35.8 MET/hr/wk in area 1 compared to 45.9 MET/hr/wk in areas 4 and 5) ($P<0.05$).

3.4.6 Differences in energy expenditure controlling for gender and DED

Table 3.2 : Results from regression analysis assuming linear association between log (METs) and DED area

Dependent variable	Gender	DED
	β and SE	β and SE
log METS	-0.338 (.06)	0.066 (.025)
	P=0.000	P=0.01

Table 3.3: Results not assuming linear association, but comparing each level of deprivation with level 1 (reference group). (DED 5 only one significant after adjusting for gender effect).

Dependent variable	Gender	DED2	DED 3	DED 4	DED 5
	β and SE	β and SE	β and SE	β and SE	β and SE
log METS	-0.331	-0.040 (0.08)	0.136 (0.13)	0.112 (0.10)	0.432
	(0.06)	P=602	P=0.296	P=,259	(0.16)
	P=0.000				P=0.007

3.4.7 Average number of activities participated in throughout the calendar year

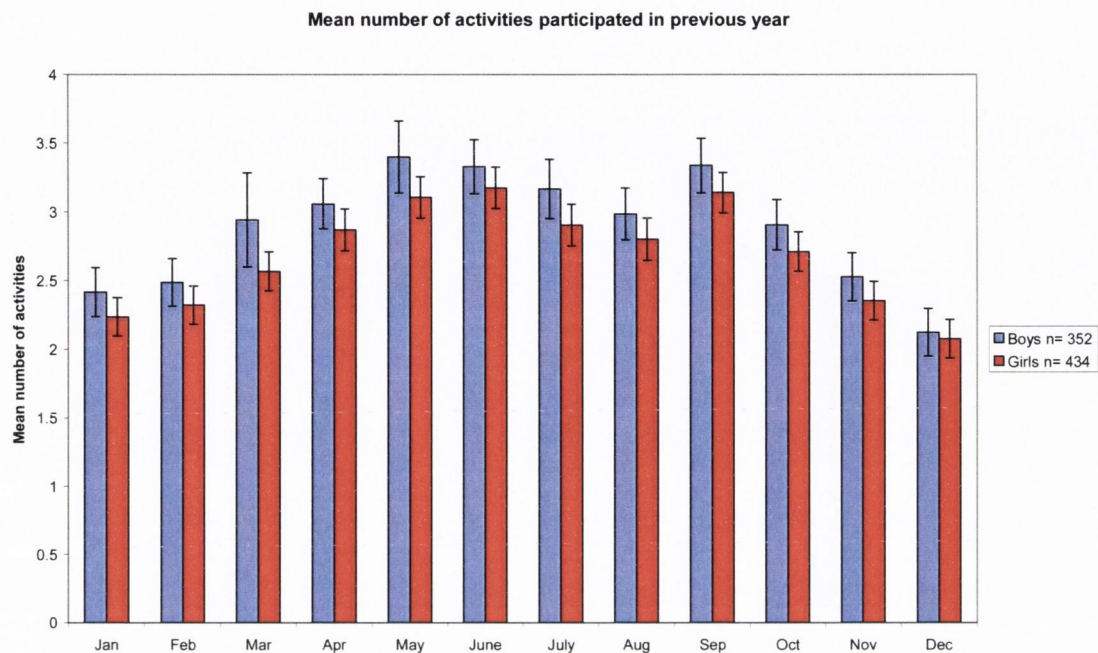


Figure 3.4: Distribution of number of activities (with 95% C.I. s) performed throughout the year

Figure 3.4 presents the average number of activities participated in throughout the calendar year for both genders. It can be seen that the highest number are during the summer months and the lowest in the winter months.

3.4.8 Teachers responses

Sixty-eight questionnaires were sent to teachers and 49 were returned giving a teacher response rate of 72%. Teachers reported that they had one or two PE classes per week, with 50% having one and 50% having two. The time duration of PE classes ranged from 10-60 minutes. All but one teacher reported that it was obligatory for children to participate in the class. The location where PE took place varied, often depending on the weather, but all

schools reported having a gym or hall for PE sessions. The mean time per session that children were reported to spend in vigorous activity was 15 minutes with a range of 5-45 minutes. Where applicable both genders did the same activities.

3.5 Discussion

This study differs from many others in that it examines physical activity levels in children of a young age and from differing socio-economic groups.

3.5.1 Return rates

The return rates of the questionnaires ranged from a mean of 38% in area 5 to a mean of 53% in area 1, but within these the ranges were large. As the number of schools in each area were not similar, and an overall 10% sample was selected, the number of subjects in areas ranged from 473 in area 1 to 29 in area 5. With small numbers in some areas it was difficult to compare data acquired with respect to differences in socio-economic status. Because of the very low response rate in area 5 it is possible that the results from this area may not be totally representative. Principals in some schools commented that literacy or language problems could have influenced response rate. It was not possible to chase up non-responders as it was the headmaster/teachers of the children who were responsible for the circulation and collection of questionnaires.

3.5.2 Participation in hard exercise

It was found that 39% of children were participating in hard exercise for at least 20 minutes 3 or more times per week. This figure is low when compared to the previous figure of 53% of an older age group (9-17 years) who reported exercising 4 or more times per week (SLAN, 1999). However, the fact that a premise of at least 20 minutes was stipulated may be a reason for this lower result. Prolonged exercise may not be the natural choice of younger children,

where activity may be typically intermittent (Armstrong and Bray, 1991). Fewer girls were participating in hard exercise, and this gender difference was also seen in a recent Irish study where 45% of girls, compared to 62% of boys, reported exercising 4 or more times per week (SLAN, 1999). Gender differences in the amount of vigorous physical activity done has been reported by others with girls doing less than boys of a similar age (Armstrong and Bray, 1991; Falgairette *et al.*, 1996).

3.5.3 Energy expenditure in regular physical activity

The energy expenditure in regular physical activities was higher in males implying that boys participate in more vigorous activities for longer and/or more frequently than girls. Common activities among boys such as rugby, hurling and soccer, require on average higher energy expenditure when compared to some female activities of this age such as ballet. It was also found by using regression analysis that both gender and DED affect physical activity levels. However, the only DED area that was significantly different from DED 1 was area 5 after adjusting for gender effect. Of concern is that 19% of girls and 11% of boys were reported to be engaging in less than the minimum recommendation of physical activity based on a level of 12 MET/hr/week. When the more recent recommendations are considered, 58% girls and 41% of boys are failing to achieve this minimal level. This study, however, only addressed regular physical activity and not the intermittent sporadic activity that is naturally seen in children of this age if given the opportunity. There was a difference in energy expenditure in regular activity between children in areas of deprivation index 5 combined compared to those in area 1. However, caution in interpretation may be required, because of the difference in numbers and low response rate in area 5. The effect of age on physical activity was not investigated as the band was narrow and the specific date of birth was not obtained in the survey.

In terms of the numbers of activities children participate in it can be seen that there was an increase in number during the summer months, which may be partly explained by weather effects. Of particular interest is that the peak of the number of activities occurred during the summer months spent at school (May, June and September), possibly indicating the increased activities offered within the schools during this time.

3.5.4 Amount of Physical Education during school hours

All schools had either 1 or 2 periods of PE per week, with a mean duration of 20-30 minutes. Teachers reported that the locations for PE were appropriate, but some teachers stated there was a need for more time during the week to be devoted to PE, as they were concerned about the general levels of physical activity in children.

3.5.5 Participation in light exercise

Overall 57% of children reported to engage in 20 minutes of light exercise at least 3 times per week, and there were no significant differences between genders. Other studies have reported minimal or no difference in moderate activity between genders (Armstrong and Bray, 1991; Falgairette *et al.*, 1996). Of concern is the lack of 20 minutes of light activity 3 times per week in 43% of the sample. Activities such as cycling and walking are important lifestyle activities that are associated with the prevention of many diseases in adulthood. The formation of these lifestyle habits in childhood may influence activity patterns in adulthood (Telema *et al.*, 1996). Of interest was the difference in percentages walking to school between children in area of deprivation index 1 and areas 4 and 5 (i.e. comparing those of higher socio-economic status to lower). Overall, thirty three percent of children were driven to school by car and 5% by bus. Forty percent walked and 20% walked part of the way. These figures are in contrast to a previous Irish study in 1990 where 77% of primary school children were driven to school by car (Watson and Drummy, 1993). It is not clear in that

study whether some subjects were from rural areas where distances to school may prevent children walking to school.

3.5.6 Time in sedentary activities

Watson (1993) reported on a mean of just under 3 hours spent watching TV per day by Irish children. In the U.S. it has been reported that 67% of children watched TV for at least 2 hours per day (Andersen *et al.*, 1998). The figure in this study of 77% spending at least 2-3 hours per day in front of a screen is higher, but the question did include PC games as well as TV. This amount of time spent sedentary each day is of concern, because of the relationship between the amount of time spent sedentary and body fat (Andersen *et al.*, 1998). There were no differences seen in the energy expenditure spent in participation in regular activity for those spending more or less than 3 hours per day in front of a screen. However, the time spent sedentary by the children may be at the expense of un-organised spontaneous activity which was not assessed in this study. Regular activities such as swimming, ballet, rugby and soccer tend to be planned and timetabled in advance, whereas TV is watched at times when the child is free from school or organised activities.

3.5.7 Limitations of the study

One limitation of the study was that the recording of data in the questionnaire was based on the parents' subjective evaluation of the frequency and duration of activities, which could lead to an overestimation of activity. It is acknowledged that, while the questionnaire used was validated in teenagers it was completed in this study by parents due to the relatively young age of the children studied. Return rates from areas of lower socio-economic status were lower than those of higher which may have led to bias. Another limitation was that the questionnaire investigated regular physical activity and did not take into account parts of the day when the child may have been very active in non-organised play in the school yard,

garden or park. When children are playing outside parents may be unaware of the amount of activity their children engage in. It has also been documented that children of this age may not often participate in vigorous activity of 70% of maximum heart rate for 20 minutes or more in one session. Armstrong *et al.* (1990) found that 5 minute periods of intense activity, as measured by continuous heart rate monitoring, in sixth year (primary) children, were common and that few children spent periods of 20 minutes or longer with heart rates above the recommended threshold (140bpm). Objective measures of physical activity such as heart rate monitoring or accelerometry, would not have been feasible for a study involving nearly 800 subjects.

3.6 Conclusion

This study presents data on physical activity levels in a large sample of Dublin school children in the 7-9 year age group. While direct comparisons to other studies are difficult due to different methodologies, many of the findings of this study are similar to those in many other published reports. Despite the limitation of the method of measuring regular activity, the data support findings of previous studies that boys participate in more physical activity than girls, even at this young age (SLAN, 1999; Armstrong *et al.*, 1990). It was reported that a number (41% boys and 58% girls) were not adhering to current activity recommendations. However, the limitation of not assessing non-organised, intermittent activity needs to be addressed, as this type of activity is natural in young children. Furthermore the question of the influence of overall activity and fitness levels requires investigation.

It can be seen from this study that there is a need to quantify activity levels objectively. The objectives of the next study are to validate a commercially available device for the measurement of both activity and inactivity in children.

CHAPTER 4: VALIDATION OF THE RT3 IN THE MEASUREMENT OF PHYSICAL ACTIVITY AND INACTIVITY IN CHILDREN (STUDY TWO)

4.1 Introduction

Measurement of physical activity and inactivity in children poses many challenges. Theoretically, the three - dimensional nature of tri-axial accelerometers would be appropriate for measuring the sporadic activity seen in young children. The RT3 (Stayhealthy Inc, Monrovia, CA) is a tri-axial accelerometer, which the manufacturers claim is comparable to its predecessor : the Tritrac. The Tritrac has been validated in adults and children by comparing energy expenditure against indirect calorimetry (Leenders *et al.*, 2003; Welk *et al.*, 2000), heart rate (Welk *et al.*, 1995) and scaled oxygen consumption in both laboratory settings and a field environment (Hendelman *et al.*, 2000; McMurray *et al.*, 1998). The Tritrac can distinguish between the various intensities of walking and jogging on level ground, and can be used to categorize light, moderate and vigorous levels of physical activity (Hendelman *et al.*, 2000 ; Jakicic *et al.*, 1999; Leenders *et al.*, 2003; Nichols *et al.*, 1999). However, limitations have been found in that monitors, although reliable from day to day and sensitive to changes in speed, could not detect changes in grade of surface or terrain (Fehling *et al.*, 1999).

A more recent tri-axial accelerometer is the RT3 from Stayhealthy Inc (Monrovia, CA). The RT3 is smaller in size than the Tritrac, which may make it easier to use in the examination of physical activity in children. It can be clipped to a waist belt using the unit's holster. There is the ability for data to be collected in 1-min or 1-sec intervals and to be recorded for up to 21 days. The RT3 integrates acceleration from the three planes to yield a vector magnitude (the square root of the squared sums of "activity counts" in each vector). The RT3 has been found to be reliable in the measurement of six activities in a female of 24 years (Powell *et al.*,

2004). Rowlands *et al.* (2004) investigated the validity of the RT3 in the assessment of physical activity in 10 boys and 10 adult males and it was found to correlate significantly with oxygen consumption in boys ($r=0.87$, $P<0.01$) and in men ($r=0.85$, $P<0.01$).

The aim of this study was to assess the validity of the RT3 accelerometer in children in the estimation of energy expenditure in inactivity, light, moderate and vigorous activity in a laboratory setting. In addition, the validity of the RT3 in measuring walking on an incline was also investigated. This present study differs from that of Rowlands *et al.* (2004) where the validity of the RT3 with respect to children was examined only in boys. This present study also investigated the validity of the RT3 in the measurement of inactivity in terms of sitting quietly watching DVDs or playing computer games. The ability of the RT3 to classify specific intensities of activity was also investigated.

4.2 Methodology

4.2.1 Objectives and design

The aim of this study was to assess the validity of the RT3 accelerometer in the estimation of energy expenditure in inactivity, light, moderate and vigorous activity in children. In addition, the validity of the RT3 in measuring walking on an incline was also assessed. The ability of the RT3 to classify specific intensities of activity was also investigated. The methods used compared energy expenditure estimated via the monitor and that obtained by the gold standard approach of indirect calorimetry.

4.2.2 Sampling and subjects

Subjects were recruited through staff in the Trinity Centre for Health Sciences, St James's Hospital, Dublin 8 through poster advertising. The inclusion criteria were children of 7-12 years of age who had no restrictions to mobility. Thus the sample was a convenience sample. Each subject gave written consent after being briefed on the protocol and safety, and consent was obtained from the parents of the children. Approval for this study was granted by the Human Ethics Committee of the Faculty of Health Sciences, Trinity College Dublin.

4.2.3 Measures

(a) Indirect calorimetry

Indirect calorimetry was measured by the Oxycon Mobile System. Expired respiratory gases were collected, and oxygen consumption was measured on a breath - by - breath basis using the Oxycon Mobile system (Viasys Healthcare). The Oxycon Mobile has been compared to an accurate reference system (Oxycon Pro) and no significant differences in VO_2 in ml/kg/min were found during an endurance cycling test up to 3000 ml/min (or approx 42 ml/kg/min for a 70 kg male) (Perret and Mueller, 2006). The system records data breath-by-breath, collected through a facemask which is transmitted to the host computer via telemetry. It is a light (950g) battery operated portable system that can be worn on the back and consists of a sensorbox (for gas measurement) and a data exchange unit (which sends data to the host computer).

As the exercises in this study were performed on a treadmill, the sensorbox and data exchange unit were attached to the cross arm of the treadmill. At the beginning of each day the system was calibrated. Two standard gases (one of room air and one mixture of 16% O_2

and 5% CO₂) were used for the calibration. Children were fitted with a paediatric face mask unless an adult mask was required for size.

(b) RT3 tri-axial accelerometer

The RT3 can assess activity in 3 planes and records intensity, frequency and duration of activity as well as the volume accumulated over the time it is worn (Chapter 2, pages 81-82). This accelerometer is light and involves little hindrance to the wearer and is placed on the waist band or hip pocket. The age (yr), gender, height and weight are entered into each device to set a profile from which activity and resting energy expenditure is calculated. The interval of data collection was set at 1 minute and the output expressed as kilocalories per minute and mean counts per minute. Physical activity can be expressed as total energy expenditure, which is estimated from the data on the subject's age, weight, height and gender, or as minutes per day spent in activity of different intensities. Activity can be quantified in terms of minutes in light (VM:100-970), moderate (VM: 970-2333), vigorous (VM: 2333-3500) (Rowlands *et al.*, 1999) and hard and above activity (VM: >3500) (Rowlands *et al.*, 2004) .

4.2.4 Laboratory testing

Subjects were requested not to eat for 3 hours before commencement of the test to avoid the influence of the thermal effects of food on energy expenditure values. Upon entry into the laboratory, height was measured to the nearest 0.1 cm using a stadiometer (Seca 220) and weight was measured to the nearest 0.1kg using an electronic scales (Seca) with participants in normal sportswear (T-shirt, shorts) and shoes removed. Subjects were familiarized with the treadmill (Viasys LE 300 CE) at all activity speeds. Participants were fitted with the RT3 accelerometer (Stayhealthy Inc.) to the waistband on their right side. The same accelerometer was used by all subjects. A face mask was strapped on and attached to the Oxycon mobile system.

Energy expenditure during inactivity was measured with the subjects sitting for 5 minutes watching a DVD and then for a further 5 minutes while the child sat and played a hand held gameboy. The exercises included: walking at 3 km/h, brisk walking/running at 6 km/h, brisk walking/running at 6 km/h on an incline of a 10% gradient, and running at 9 km/h. These speeds were believed to be representative of typical daily activities (light, moderate and vigorous intensities). Following an initial 10 min period of inactivity to collect baseline/inactivity data, each exercise was performed for 5 min and followed by a 5 min rest period where the subject was seated in a chair placed on the treadmill. Subjects watched a popular children's cartoon on a DVD during all rest periods and were requested to reduce extraneous movements, and refrain from talking to minimize expired air changes. For safety reasons a researcher stood beside the treadmill at all times. The child was instructed to walk/run at the required pace set and could hold the cross bar if required. It was decided prior to the study that subjects of less than 9 years of age would not do the final workload of running at 9km/h (this was based on pilot work where a number of children of this age had to hold on to the side bars of the treadmill during running). Therefore the number of subjects for 9km/h was 14.

4.2.5 Data collection

A stopwatch was used for synchronizing treadmill exercise stages with expired air collection and RT3 recording. Following each exercise session, the minute by minute data from the RT3s were downloaded to a computer using the RT3 docking station. The metabolic measures were collected continuously from 5 minutes prior to the beginning of the first 5 minute resting period to the completion of the final stage of the running at 9km/h. The data used for comparison between the methods was the average of the last two minutes of each activity. Data used for comparison was the energy expenditure via the RT3, compared to the

energy expenditure as measured by the Oxycon Mobile, and scaled oxygen consumption was compared to the activity counts for all activities.

4.2.6 Data analysis

The data were expressed as means and standard deviations. Limits of agreement (LOA) and 95% confidence intervals between the metabolic and RT3 energy expenditure estimates were calculated, according to the method described by Bland and Altman (1986). The data were presented graphically, comparing the differences between the RT3 and the metabolic measures with the average values. This method was used because, in clinical measurement, a high correlation does not necessarily mean that the measures agree but that there is a strong relationship between the measures (i.e. the points lie on a straight line). When a new measure is being examined there is a need to know how much the new measure is likely to differ from the gold standard. The Bland and Altman limits of agreement method plots the differences between the methods against their mean, and the bias is estimated by the mean difference and the standard deviation of the differences. The means and confidence intervals for each workload were presented graphically to determine if there were significant differences between measures for each activity. Repeated measures and test of interaction was also performed. Data for each activity in terms of Vector Magnitude is also presented. SPSS (version 12) was used for data analysis and Prism TM software was used for creating the graphs.

4.3 Results

4.3.1 Subject characteristics

Twenty children aged between 7-12 years completed the study (8 girls and 12 boys). The descriptive data on the ages, heights and weights of the subjects is presented in table 4.1.

Table 4.1: Baseline data on study subjects

Gender	Age in years (mean ± SD)	Height in cm (mean ± SD)	Weight in kg (mean ± SD)
Males (n=12)	8.2 ±1.3 years	136± 10.8 cm	30.8±7.6 kg
Females (n= 8)	10.2 ±1.6 years	144± 13.7 cm	37.7 ± 10.2

4.3.2 Energy expenditure: metabolic compared to energy expenditure via the RT3

The following graphs (Figures 4.1 to 4.5) are Bland and Altman plots of the data on energy expenditure measured in the two ways. Both measures are in kcal/min . Resting data was obtained with the child sitting quietly for 5 minutes followed by a further 5 minutes sitting playing game on a handheld console. The data for the first 5 minutes of resting is presented in figure 4.1 (i.e. child sitting quietly). The data for the second 5 minutes when the child played the hand held game was very similar and therefore not presented graphically. Table 4.2 presents the data for each activity by both VO₂ as measured by indirect calorimetry and by the Vector Magnitude obtained by the RT3.

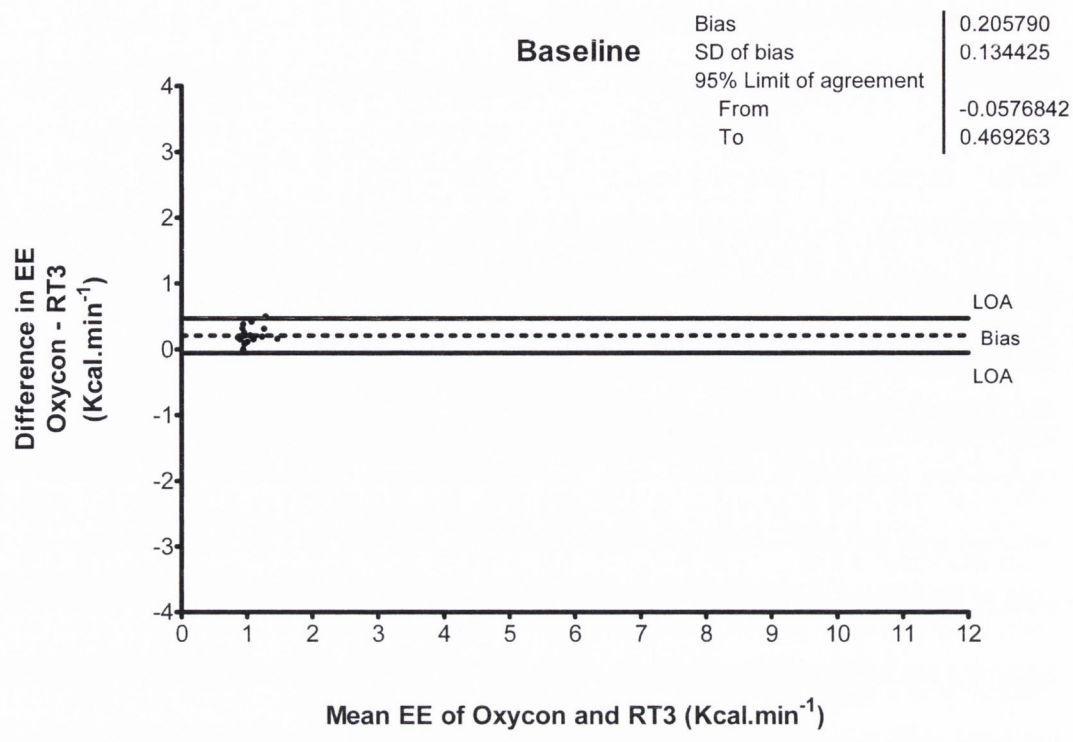


Figure 4.1 : Bland and Altman plot of energy expenditure measured by the RT3 and Oxycon in sitting.

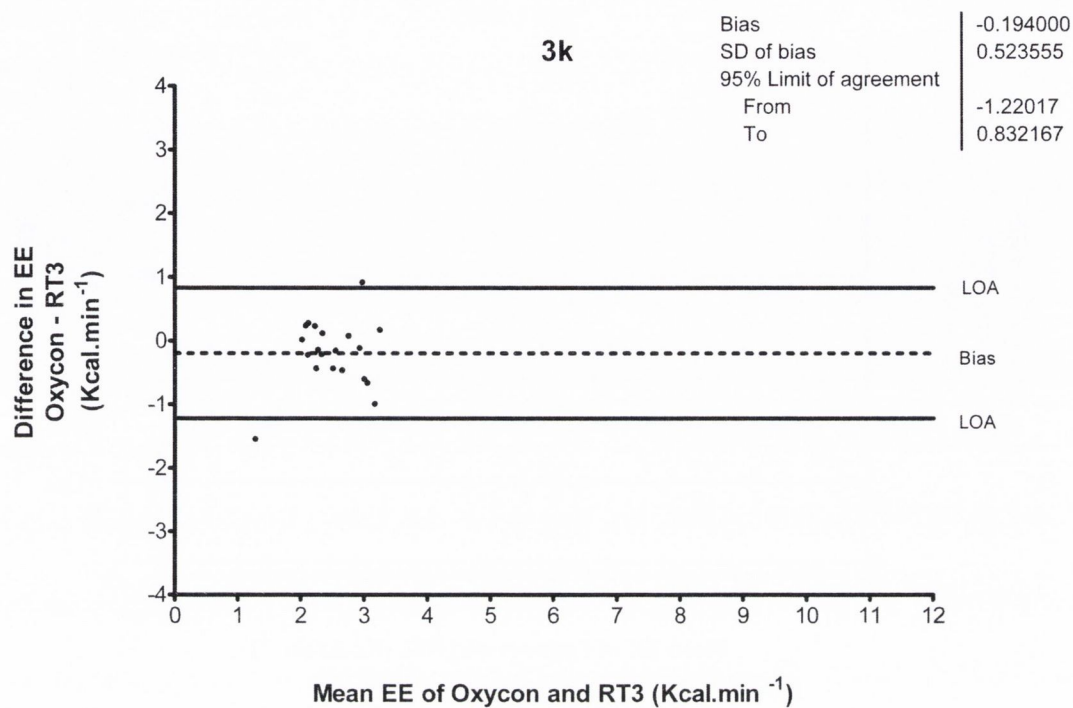


Figure 4. 2 : Bland and Altman plot of energy expenditure measured by the RT3 and Oxycon for walking at 3km/h

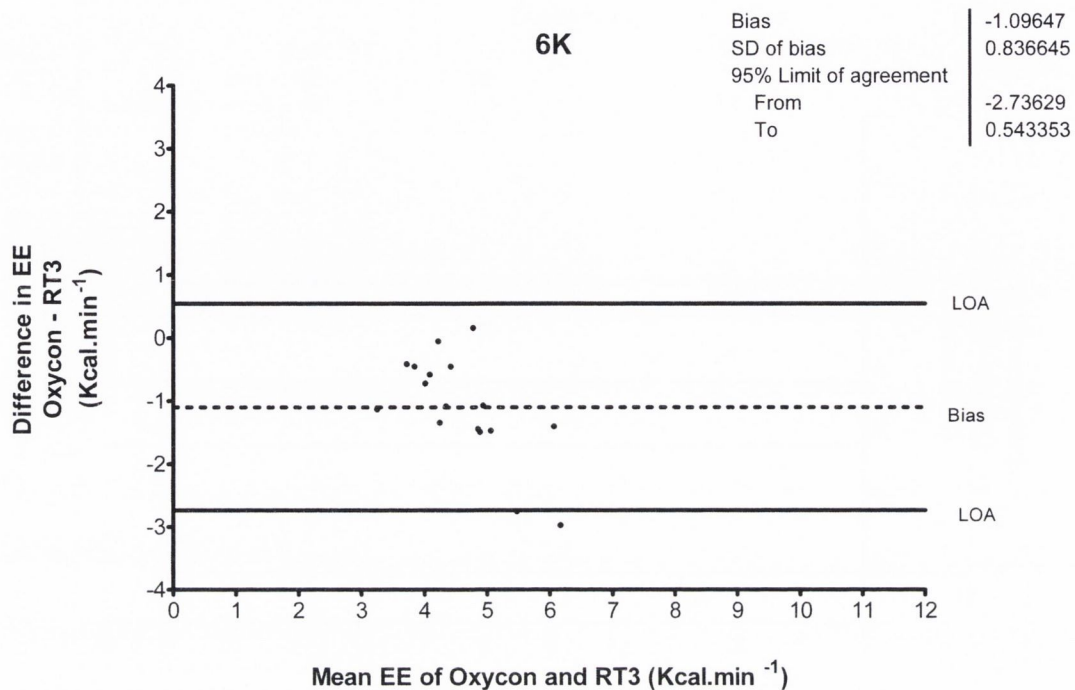


Figure 4.3: Bland and Altman plot of energy expenditure measured by the RT3 and Oxycon in walking at 6km/h

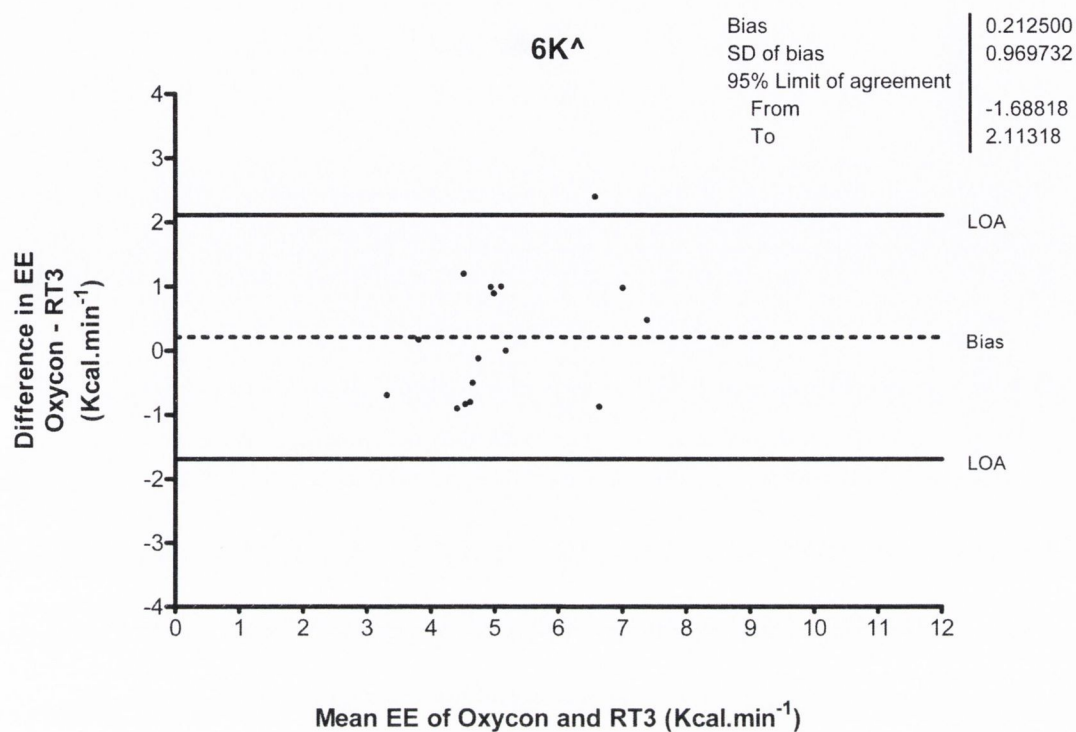


Figure 4.4: Bland and Altman plot of energy expenditure measured by the RT3 and Oxycon for walking at 6km/h on an incline of 10 degrees.

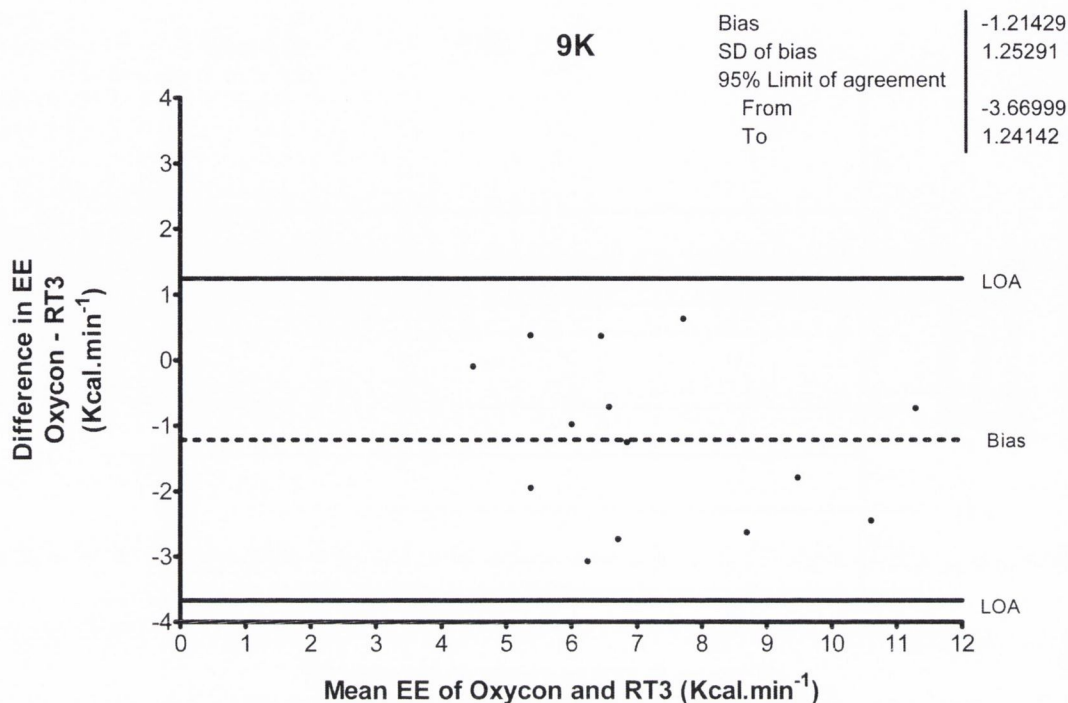


Figure 4.5: Bland and Altman plot of energy expenditure measured by the RT3 and Oxycon for running at 9km/h

To assess the relationship between each activity measure in a linear progression, a repeated measures analysis was performed. It would not have been appropriate to do a Pearson correlation for the overall data as each point was not independent (i.e. the same subjects performed each workload). The repeated measures was carried out, and as can be seen in figure 4.6, there was no statistical difference between methods (overlap of confidence intervals). A test for interaction was performed to determine if the trend in both lines was similar or different. This was analysed for resting, walking at 3 km/h and walking at 6km/h (see figure 4.7). The activity of walking at 6 km/h uphill was removed from this analysis due to the established limitation in the accelerometer measuring walking on an incline. Overall,

the trend was different as seen by the test of within-subject effects using both activity methods test for interaction ($P<0.001$), i.e. the slope of the lines were different (not parallel) (see Figure 4.7).

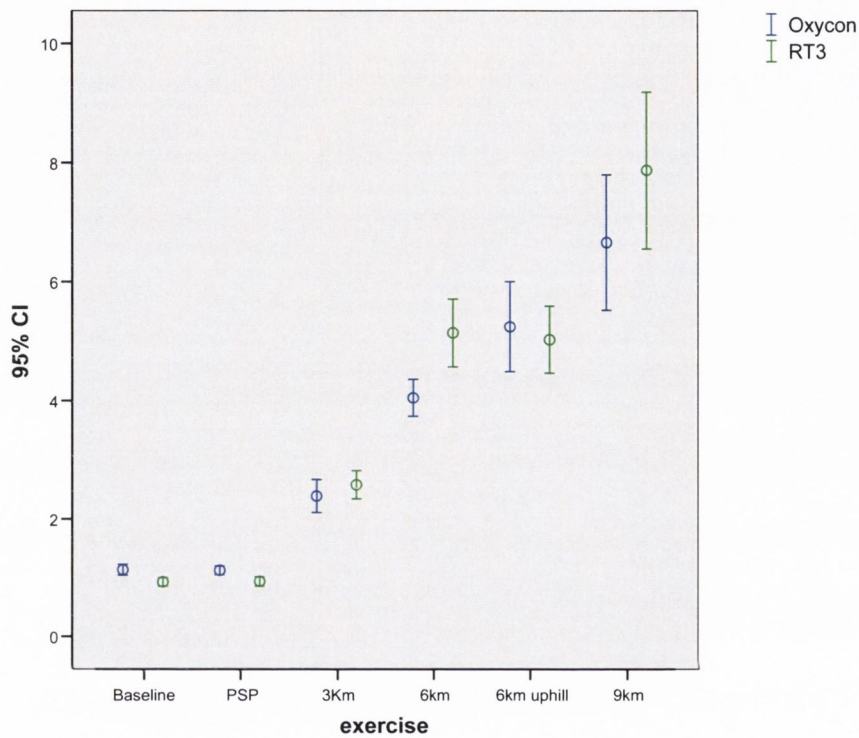


Figure 4. 6: Means and 95% CIs for repeated measures of energy expenditure measured by the RT3 and the Oxycon. (PSP: sitting playing games console).

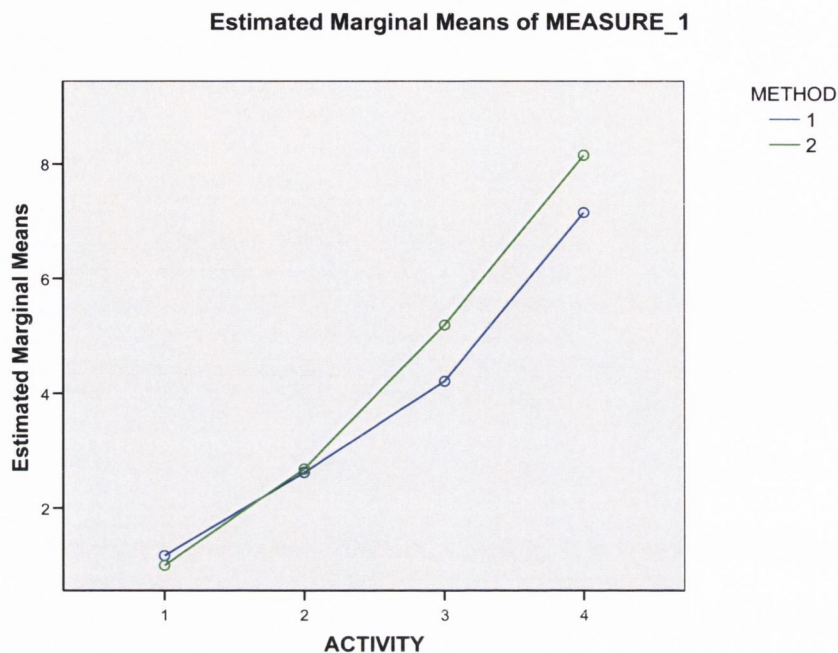


Figure 4.7: Relationship between the means of the measures where method 1 is indirect calorimetry and method 2 is the RT3. The activity points are : 1= resting, 2= walking at 3km/h, 3= walking at 6km/h, 4=running at 9km/h.

Table 4.2. VO₂ and accelerometer vector magnitude by activity

Activity	VO ₂ (mean and SD)	Vector Magnitude (mean and SD)
Sitting quietly	7.7 ± 1.7 ml/min	40.4 ± 33.9
Sitting playing Gameboy	7.9 ± 2.1 ml/min	45 ± 57.2
Walking 3km/h	17 ± 4.2 ml/min	1973 ± 261
Walking 6km/h	25.6 ± 5.3 ml/min	3355 ± 775.4
Walking 6km/h 10°	32.2 ± 5.8 ml/min	3365 ± 571.9
Running 9km/h	40.5 ± 4.5 ml/min	5798 ± 590.0

4.4 Discussion

The RT3 is a recently developed tri-axial accelerometer. This study investigated the validity of measuring energy expenditure via the RT3 against the criterion of energy expenditure measured with the Oxycon Mobile unit during inactivity, walking, walking on an incline and running on a treadmill. The results of this study demonstrate that the RT3 appears to provide a valid measure of activity and inactivity in girls and boys of 7-12 years.

The relationship between energy expenditure measured by the two different methods was investigated, using limits of agreement and repeated measures analysis, for each activity measurement. The limits of agreement were found to be very close for inactivity and walking at 3km/h. Walking at 6km/h on an incline of ten degrees and on the level and running at 9km/h showed slightly wider limits of agreement. In all of the latter the bias was below zero indicating the RT3 overestimated energy expenditure. While overall the RT3 overestimated compared to the Oxycon, there was no significant difference between them. In terms of the repeated measures, there was no significant difference between the methods for each activity measured (as seen by overlapping confidence intervals).

In this study the RT3 did not demonstrate any difference in Vector Magnitude counts between walking at 6km/h on the flat and walking on an incline of 10 degrees. This could be explained by omission of the usual overestimation of the RT3 due to the increase in energy expenditure related to the gradient. This would be similar to the findings with other accelerometers which could not detect increases in gradient. In addition to the validity in terms of measuring the energy expended in physical activity, as described above, the ability of the RT3 to define specific intensities of activity is an additional strength of the measurement tool. This study differs from other validity studies in terms of analysis as others have not used limits of agreement to compare results from two measures. The time spent in

specific intensity of activity, in addition to time spent inactive, may be a focus of research into the specific influences of activity on fitness, body composition and health variables. Previous studies on other tri-axial accelerometers (Hendelman *et al.*, 2000; Mc Murray *et al.*, 1998) have found a strong relationship between scaled oxygen consumption and the activity counts. Rowlands *et al.* (2004) investigated correlations between the RT3 activity counts and energy expenditure via gas analysis at different speeds of walking and unregulated activities which included hopscotch, kicking a ball and sitting. It is difficult to interpret the relationship between activity counts and VO_2 for inactivity as in the analysis a relatively high correlation ($P < 0.01$) was found between counts and VO_2 for the unregulated activities combined. In the results of the study reported by Rowlands *et al.* (2004) the data from the unregulated activities were plotted on a scatter-plot which graphically suggests a close relationship, but an individual correlation for sitting was not reported. The classification of intensities of activity appears to be possible with the RT3, and ranges for the activities measured were just under 2000 counts per minute for walking at 3km/h and just over 3000 counts per minute for walking at 6km/h. Running at 9km/h achieved over 5000 counts per minute.

The accurate measure of inactivity is of particular importance as so much of the day is spent in sedentary activities in both adults and children. The ability of the RT3 to measure inactivity accurately does provide a means of determining periods of inactivity in those with and at risk of diseases associated with inactivity. In children there is concern about the time spent sedentary, and the RT3 may provide a suitable measure of the time spent in inactivity. The monitors can be worn during most activities of daily life and, as it is unobtrusive, does not interfere with regular activity.

4.5 Conclusion

In summary, the RT3 was found to be a valid measure of inactivity and walking and running at speeds of 3km/h, 6 km/h and 6km/h on an incline of 10 degrees and 9km/h in this cohort of children aged 7-12 years. In addition, the RT3 permits classification of specific activity levels. Due to these findings, the use of the RT3 accelerometer was deemed appropriate for the objective measurement of physical activity levels.

CHAPTER 5: THE RELATIONSHIP BETWEEN BODY COMPOSITION AND THE INTENSITY OF PHYSICAL ACTIVITY, INACTIVITY, FITNESS AND BLOOD PRESSURE IN 7-9.9 YEAR OLD CHILDREN (STUDY THREE)

5.1 Introduction

It appears plausible to assume that higher levels of physical activity in children result in a more favourable body composition. As discussed in Chapter 1, section 1.2, studies investigating the relationship between activity levels and body composition have demonstrated conflicting results, with some finding no relationship (Raustrop *et al.*, 2004; Hansen *et al.*, 2005), while others have found that higher activity levels were correlated with lower fat mass (Kemper *et al.*, 1999; Ara *et al.*, 2004; Guillaume *et al.*, 1997; Rowlands *et al.*, 1999; Rennie *et al.*, 2005). There is further uncertainty when one examines gender differences as some investigators have found a relationship between levels of physical activity and body composition in boys but not in girls (Guerra *et al.*, 2006; Trost *et al.*, 2003; Rush *et al.*, 2003).

Studies examining the relationship between intensity of activity and body composition have also found varying results. Abbott and Davies (2004), in a study of 47 subjects aged 5-10.5 years, found that times spent in vigorous and hard activity were significantly correlated to percentage body fat but not to BMI. Moderate intensity activity, however, was not found to correlate with measures of body composition. In pre-school children it has been found that the amount of moderate to vigorous activity was significantly greater in non-overweight boys compared to overweight boys but no such relationship was seen in girls (Trost *et al.*, 2003). The relationship between time spent sedentary and body fat was investigated in a one year longitudinal study in adolescent girls, and an increase in inactivity was found to be associated with an increase in BMI (Berkey *et al.*, 2003).

A definitive understanding of the relationship between activity levels and body composition in children may not be possible due to methodological differences in the above studies. Firstly, various techniques have been used to determine body composition, e.g. BMI, waist circumference and skin-folds. Secondly, there is a wide variation in the methods used to measure physical activity, with many studies using subjective methods (Ribero *et al.*, 2004, b; Ara *et al.*, 2004; Guillaume *et al.*, 1997; Guerra *et al.*, 2006; Berkey *et al.*, 2003). In studies using more objective methods (e.g. accelerometers), there has been limited examination of the influence of the various intensities of physical activity, including inactivity, on body composition (Rowlands *et al.*, 1999; Trost *et al.*, 2003).

As was discussed in Chapter 1, section 1.2, there is increasing evidence to suggest that low levels of physical activity in children and adolescents are related to increased levels of cardiovascular risk (Ribero *et al.*, 2004 a; Bouziotas *et al.*, 2004). A recent investigation from the European Youth Heart Study Group found that the odds ratio for clustered risk was 2.03-3.29 in children from the least active quintiles of physical activity compared to the most active (Anderson *et al.*, 2006).

Activity is one risk factor for cardiovascular disease. Other factors that could be examined in children include fitness and blood pressure. While it would have been interesting to measure blood cholesterol, glucose tolerance and inflammatory markers this was not possible as schools would not agree to blood sampling in school grounds. Thus this study investigated the relationships between body composition, intensity of physical activity and inactivity, aerobic fitness and blood pressure.

This study has been published in the British Journal of Sports Medicine.

Hussey, J., Bell, C., Bennett, K., O'Dwyer, J., Gormley, J. (2007). The relationship between the intensity of physical activity, inactivity, cardiorespiratory fitness and body composition in 7-10 year old children. British Journal of Sports Medicine, 41, 311-316.

5.2 Methodology

5.2.1 Objectives

The aim of study three was to investigate the inter-relationships between body composition, physical activity and aerobic fitness. The specific objectives of this study were:

- To determine the relationship between body composition and moderate, vigorous and hard activity in children aged 7-9.9 years
- To determine the relationship between body composition and time spent sedentary in children aged 7-9.9 years
- To determine the relationship between body composition and aerobic fitness levels in this cohort
- To determine the relationship between body composition and blood pressure in this cohort

The design used was a cross-sectional study, and the limitations of such have been acknowledged in Chapter 2 (page 71).

5.2.2 Sampling and subjects

Stratified (geographically) random sampling was used in this cross sectional study. The list of schools in the Dublin area was available from the Department of Education and Science

website (www.education.ie). Schools were randomly selected (by means of a random sampling table) from each of the four Dublin borough areas (Dublin Borough, Dublin Fingal, Dublin South, Dun Laoghaire-Rathdown) on a proportional basis. As it was anticipated that not all schools contacted would participate a list of 28 schools (which incorporated a proportionate sample from each area) were selected (by a random numbers table). This resulted in 10 from Dublin Borough, 6 from Dublin South, 7 from Dublin Fingal and 5 from Dun Laoghaire-Rathdown. Principals of the schools were contacted, the aims of the study were explained and the call was followed up with a letter to be brought to the school boards for approval, where necessary. Once a school had agreed to participate in the study letters to parents and consent forms were distributed (see Appendix 4 for letter to parents).

The primary sampling unit was the school, and within each school the subjects were children from second class aged 7-9.9 years. Children with conditions that could have led to limitations in physical activity and mobility, i.e. those with musculoskeletal or neurological impairments, were excluded. In order to determine a correlation of 0.2 or greater between activity levels and BMI, it was calculated that 195 children would be required for the study to have 80% power of detecting a correlation and a two tailed level of significance of 5%. The study was powered based on similar work by Gutin *et al.* (1990) in 5-6 year old children. Ethical approval for the study was obtained from the Joint Research Ethics Committee of the St James's Hospital/ Adelaide and Meath, incorporating the National Children's Hospital.

5.2.3 Measures

(a) Body composition

Stature (standing height) was measured standing using a portable stadiometer (SECA, Vogel and Halke, Germany) to the nearest mm. The subject was instructed to “stand as tall as

possible". The subject in light clothing (school tracksuit) and without shoes stood upright against the stadiometer with feet together, and the head of the instrument was moved down to make contact with slight pressure onto the vertex of the skull. Weight was measured using an electronic scales (SECA), to the nearest 0.1kg. All anthropometric measures were carried out by the same investigator. As mass and stature can be affected by diurnal variation (Siklar *et al.*, 2005) all measures were taken between 9 am and 10.30 am (in Studies three and four).

Body mass index (BMI) was calculated as kg/m^2 . There were no Irish growth reference data to compare measurements obtained. BMI were therefore compared to the British 1990 growth references (Cole *et al.*, 1998). The 1990 British growth reference consists of anthropometric data for height, weight and body mass index from 17 distinct surveys representative of England, Scotland and Wales (37,700 children aged 23 weeks gestation to 23 years). The reference converts measurements to standard deviation scores (SDS) that are very close to normally distributed (the means, medians and skewness for the measurements are almost zero overall). BMI measurements are therefore expressed as Standard Deviation Scores (SDS) and referred to as z scores in the text. Overweight and obesity were defined using the international cut-off points for BMI in children using age and gender (Cole *et al.*, 2000). This standard is based on average centiles which equate to a BMI of 25 and 30 at 18 years for overweight and obesity, respectively.

Waist circumference (to the nearest mm) was measured with a flexible non-stretchable tape measure at the level of the narrowest point between the lower costal border and the iliac crest (natural waist). An intra-rater reliability study for the measurement of waist circumference was carried out by the investigator. Waist circumference measurement was made on two occasions separated by 5 minutes. The subject stood erect with the abdomen relaxed and the arms hanging slightly from the body and clothing loosened so that the measure was taken on

bare skin. The researcher took the first measure of waist circumference at the level of the narrowest point between the lower costal border and the iliac crest (natural waist) using a single sided tape. The measure obtained with the tape measure was shown to and recorded by an assistant while the researcher was blind to the actual figure obtained. This was repeated five minutes later.

Thirteen children (4 girls and 9 boys) with a mean age of 7.6 years (SD 1.32) had the measures of waist circumference taken in the Exercise laboratory in the Trinity Centre for Health Sciences. The Pearson correlation coefficient was $r=0.996$, and therefore reliability of the Researcher was demonstrated. As the British Growth Standards did not contain waist circumference data measures of waist circumference were compared to percentiles in British children (McCarthy *et al.*, 2001).

(b) Objective quantification of physical activity in children

The RT3 accelerometer (Stayhealthy Inc, Monrovia, CA) was used for the objective measurement of physical activity. Activity was quantified in terms of minutes in light (VM:100-970), moderate (VM: 970-2333), vigorous (VM: 2333-3500) (Rowlands *et al.*, 1999) and hard activity (VM:>3500) (Rowlands *et al.*, 2004).

The RT3 was given to 6 children for 4 days. Four days of activity has been found to be a sufficient length of time to determine habitual activity levels in children (Trost *et al.*, 2000). An envelope with instructions on the use of the RT3 were given to the child for their parent or guardian. On return of the accelerometers, the data were downloaded to a laptop computer and saved in Excel spreadsheets. The accelerometers were re-initialised (after battery changes) and given to the next group of children. Once all accelerometers had been returned and the data downloaded, the minutes in each intensity of activity were calculated for the four days and the daily average of minutes spent in each intensity of activity was calculated.

(c) Cardiorespiratory fitness

For logistical reasons, a field test that did not require specific equipment was required. The 20-MST (20-m multistage shuttle run test), developed by Leger and Lambert (1982), was used to predict maximal aerobic capacity (version commencing at 8.5 km/h). This test requires space, field markers and an audiocassette player. The tape was checked for speed prior to testing. As the study was to be conducted in schools it was believed to be the best measure, due to availability of school yards where the test could be performed. McNaughton *et al.* (1996) investigated the relationship between the 20-MST (as described above) and directly measured VO_2 in the laboratory in children aged 12-16 years and found a correlation between the two measures of $r=0.87$ ($P < 0.001$). Other workers have also investigated the relationship between directly measured $\text{VO}_{2 \text{ max}}$ and the shuttle running test in children. Van Mechelen *et al.* (1986) found a correlation of $r=0.76$ between laboratory measured $\text{VO}_{2 \text{ max}}$ and the 20 MST in children, and Boreham *et al.* (1990) found a correlation of $r=0.87$ when the test was correlated with directly measured $\text{VO}_{2 \text{ max}}$ in 24 adolescent girls and 24 adolescent boys, leading the authors to conclude that the test was a valid predictor of $\text{VO}_{2 \text{ max}}$ in adolescent children. In 12 year old children, the 20-MST was found to be a reliable measure of cardio-respiratory fitness ($r=0.83$ boys and $r=0.76$ girls, $P < 0.03$) and was consistent in test retest reliability ($r=0.73$ boys, $r=0.88$ girls, $P < 0.01$) (Mahoney., 1992). The equation for the calculation of VO_2 is found in Appendix 1.

(d) Blood pressure

Measurement of blood pressure in the school environment was carried out using the OMRON 705 CP after 5 minutes of the child sitting, as recommended by the Task Force on High Blood Pressure in Children and Adolescents: A Working Group Report from the National High Blood Pressure Education Programme. The OMRON 705 CP is an automated digital oscillometric sphygmomanometer which has been validated by the American Heart

Association and the British Hypertension Society for the accurate clinical measurement of BP. A medium sized cuff (CM/CL) for mid arm circumference of 22-32 cm was used as this was the appropriate size for children of this age. All blood pressure readings were taken by the one investigator.

5.2.4 Procedure

The procedure involved a number of visits to each school in the study. The first visit involved measuring height, weight, waist circumference, blood pressure and cardio-respiratory fitness. A room for testing was identified (usually the gym), and the children were taken to the testing room in groups of 6-8. Children were requested to form a line and the child's details of name and date of birth, were recorded by a research assistant. The child then removed their shoes and stepped onto the stadiometer and height was measured by the researcher and documented by the assistant. The child then stepped onto the scales and weight was observed by the researcher and recorded by the assistant. Waist circumference was then measured and recorded by the researcher. The child then sat at a table and blood pressure was measured and recorded by the researcher. When all of the subjects had all measures taken and recorded, the group was brought to the school yard for the 20 - MST. The 20 meter length required had been marked with cones. Instructions were given to the children, and the tape cassette was checked for speed. The assistant ran alongside the children to keep them under close observation. The researcher recorded the level that each child reached. Once the child had reached their maximum and stopped running, they were advised to walk until the breathing returned to normal. The procedure was repeated until all children in the school visited had been examined. The RT3 was then given to 6 children for 4 days with instructions on its use. Four days of activity has been found to be a sufficient length of time to determine habitual activity levels in children (Trost *et al.*, 2000) On collection, the RT3s were downloaded, re-initialised and given to the next group of 6 children.

5.2.5 Data analysis

Activity was described in terms of minutes engaged in various intensities of activity as stated above (see 5.2.3 b above). Where between three and four days of data were recorded it was decided to average the three days (40 subjects). If more than this amount of data was missing it was not included in the analysis.

Descriptive analyses are presented for continuous data as means and 95% confidence intervals and for categorical data as percentages. Comparison of height, weight, BMI, standardised BMI, activity and VO_2 levels between genders were compared using independent t-tests, and between the body composition variable by using analysis of variance (ANOVA) (as there were three groups). Pearson correlations were calculated between standardised BMI and activity and fitness levels and recalculated for males and females separately. Correlations between two variables cannot indicate if one variable can predict the other and regression analysis was performed. With regression one assumes that a change in one variable will lead to a change in the other (Campbell and Machin, 1999). Multiple regression analysis was performed for the dependent variables of body composition (BMI z score and waist circumference) and was adjusted for age and gender. All variables other than minutes in vigorous activity (which were subsequently log transformed for analysis) were normally distributed. Significance was set at $p < 0.05$ and all analyses were performed using SPSS Version 12 (SPSS Inc.).

5.3 Results

5.3.1 Schools and subjects

Of the 28 schools contacted 12 replied positively and were scheduled into the study. The numbers in each area were: 2 from Dublin Borough, 4 from Dublin South, 4 from Dublin

Fingal and 2 from Dun Laoghaire-Rathdown. Therefore the sample was geographically spread. Data was obtained on a total of 224 children (140 girls, 62.5%, and 84 boys 37.5%). Activity data via accelerometry was obtained in 152 (68%) children (100 girls and 52 boys). The remaining 64 accelerometers were returned with less than three days of data (probably due to either not wearing the device or to the child interfering with the unit and losing the initial data set up).

5.3.2 Body composition

Height, weight, waist circumference and fitness data were obtained in 140 girls and 84 boys in a total of 12 schools.

Table 5.1 a summarises and displays the descriptive data by gender and age into height, weight, BMI and BMI z score, waist circumference and VO_2 max. Tables 5.1 b and 5.1c present data by gender and age in minutes per day spent sedentary, in moderate activity, in vigorous, in hard activity and in the sum of vigorous and hard activity. Tables 5.1 a and 5.1 b also present the difference between the genders for the described variables (last row in each). When heights of children were divided into percentiles using the British 1990 Growth Reference (Cole *et al.*, 1998) it was found that 15% of the cohort were above the 97th percentile in terms of height and 27% were above the 91st percentile. In terms of waist circumference 76% of subjects were above the 75th percentile. In terms of BMI 20.7% of girls and 20.2% of boys were overweight, with 6.3% being obese (5% of girls and 8.3% of boys). The percentile of height, BMI and waist circumference are presented in Figure 5.1.

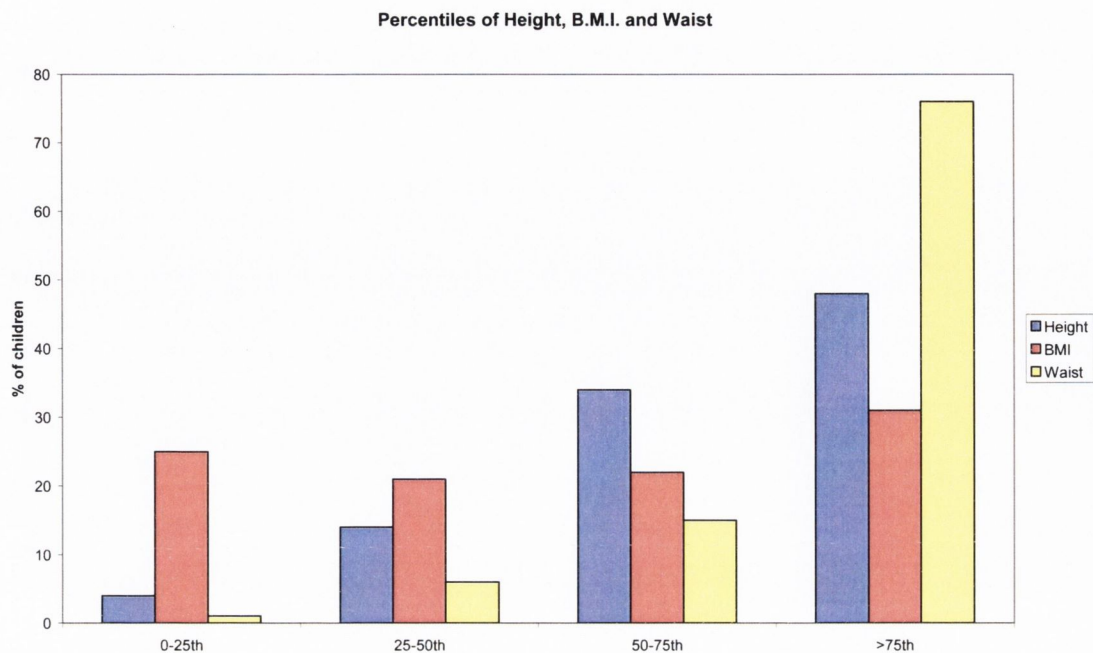


Figure 5.1: Percentiles of height, BMI and waist circumference with respect to the British 1990 growth reference (n=224)

5.3.3 Data on body composition, fitness and minutes in intensities of activity for each gender by age

Table 5.1a provides the background data on age, BMI, BMI z score, waist circumference and VO_{2max} (ml/kg/min) for each gender divided into specific age categories. The difference between the genders for each of these variable was investigated and the values presented on the last row.

Table 5.1 a: Mean and 95% C.I. s of height, body mass index, waist circumference, VO_{2max} (ml/kg/min)

Age (yrs)		Height (cm)	B.M.I.	B.M.I. z score	Waist (cm)	VO _{2max} (ml/kg/min)
MALES						
7.0 (n=37)	-7.9	132.9 (131.1, 134.7)	16.2 (15.3, 17.1)	-0.013 (-0.48, 0.46)	61 (58.7, 63.3)	51.7 (50.2, 53.2)
8.0 (n=37)	-8.9	135.2 (133.9, 136.5)	16.8 (16.0, 17.6)	0.307 (-0.07, 0.69)	62 (60.1, 63.9)	55.0 (53.6, 56.5)
9.0-9.9 (n=10)		139.3 (135.1, 143.5)	19.4 (17.8, 21.5)	1.175 (0.39, 2.00)	70 (62.5, 77.4)	51.7 (47.9, 55.5)
Total (n=84)		134.7 (133.5, 135.9)	16.9 (16.3, 17.5)	0.269 (-0.02, 0.56)	62 (60.3, 63.7)	53.2 (52.1, 54.3)
FEMALES						
7.0 (n=49)	-7.9	131.6 (130.3, 132.9)	16.6 (13.0, 20.2)	0.133 (-0.22, 0.48)	62 (60.0, 64.0)	50.5 (49.5, 51.5)
8.0 (n=81)	-8.9	133.3 (132.2, 134.4)	16.6 (16.1, 17.1)	0.047 (-0.18, 0.28)	62 (60.5, 63.5)	48.9 (48.2, 49.6)
9.0 (n=10)	-9.9	136.2 (130.6, 141.8)	17.8 (15.8, 19.8)	0.346 (-0.77, 1.46)	66 (59.8, 72.2)	49.8 (47.0, 52.6)
Total (n=140)		132.9 (132.0, 133.8)	16.7 (16.3, 17.1)	0.10 (-0.09, 0.29)	62 (60.8, 63.2)	49.5 (48.9, 50.1)
Significance		P=0.023	P=0.59	P=0.31	P=0.78	P<0.001

Tables 5.1 b and 5.1 c break down the total activity per day into the time in minutes spent in the specific intensities of activity. These are displayed divided into gender and age bands. The difference between the genders was investigated and the significance is displayed in the final row.

While there were 224 children in the study, accelerometer data was obtained on 152 subjects. The data on children with accelerometer data was compared to those without for waist

circumference, BMI z score and estimated $VO_{2\text{ max}}$. No significant differences were found. The mean waist cm for the 152 with accelerometer data was 61.68 ± 7.08 compared to 63.41 ± 7.6 for those without (no significant difference). The mean BMI z score for the 152 with accelerometer data was 0.07 ± 1.2 compared to 0.36 ± 1.2 for those without (no significant difference). The mean estimated VO_2 for the 152 with accelerometer data was 50.8 ± 4.3 ml/min/kg compared to 51.0 ± 4.9 for those without (no significant difference).

Table 5.1 b: Mean and 95% C.I. s of minutes per day spent in inactivity, light activity and moderate activity, as estimated by tri-axial accelerometry

Age (yrs)	Sedentary	Light	Moderate
MALES			
7.0-7.9 (n= 23)	927.6 (897.1,958.0)	332.7 (312.6,352.7)	115 (100.7,129.3)
8.0-8.9 (n= 23)	917.5 (880.8,954.2)	338.7 (306.1,371.2)	117 (104.7,129.3)
9.0-9.9 (n=6)	1028.5 (951.4,1105.6)	264.5 (163.4,365.6)	70 (52.4, 87.6)
Total (n=52)	935.1 (910.8, 959.4)	327.0 (307.8,346.2)	110.5 (101.0,120.0)
FEMALES			
7.0-7.9 (n=36)	945.6 (909.3, 981.9)	362.8 (335.5,389.9)	95 (83.9, 106.1)
8.0-8.9 (n=59)	970.5 (950.9, 990.2)	356.5 (320.3,392.8)	98 (92.0, 104.0)
9.0-9.9 (n=5)	1015.0 (965.4,1064.5)	342.4 (278.2,406.5)	82 (62.7, 101.3)
Total (n=100)	963.8 (945.8, 981.8)	358.0 (334.6,381.5)	96.1 (90.6, 101.6)
Significance	P=0.068	P=0.048	P=0.007

Table 5.1 c Mean and 95% C.I. s of minutes spent in vigorous activity, hard activity and hard/vigorous activity as estimated by tri-axial accelerometry

Age (yrs)	Vigorous	Hard	Vigorous/Hard
MALES			
7.0-7.9 (n= 23)	40.6 (33.2, 48.0)	23.4 (16.1, 30.7)	56 (43.8, 68.2)
8.0-8.9 (n= 23)	33.8 (25.1, 42.5)	22.3 (13.7, 30.9)	56 (43.8, 68.2)
9.0-9.9 (n=6)	21.0 (13.4, 28.6)	16.2 (12.3, 30.1)	66.3 (15.1, 117.5)
Total (n=52)	37.6 (32.3, 42.9)	22.1 (16.9, 27.3)	64.3 (53.2, 75.4)
FEMALES			
7.0-7.9 (n=36)	22.6 (19.0, 26.2)	9.4 (6.6, 12.1)	30 (24.6, 35.4)
8.0-8.9 (n=59)	26.1 (23.4, 28.8)	13.9 (10.5, 17.3)	41 (35.9, 46.1)
9.0-9.9 (n=5)	16.0 (9.95, 22.0)	6.7 (2.7, 10.7)	22.2 (14.2, 30.2)
Total (n=100)	24.5 (22.3, 26.6)	12.1 (9.8, 14.4)	37 (33.1, 40.9)
Significance	P<0.001	P=0.068	P<0.001

5.3.4 Data on the minutes spent in intensities of activity by gender and body composition grouping

Table 5.2 presents the mean and 95% confidence intervals of minutes spent in the different intensities of activity as divided by gender and body composition grouping based on international cut off points. The difference between the body composition groupings was investigated and the significance is displayed in the final row.

Table 5.2: Mean and 95% C.I. s of minutes in intensities of activity in boys and girls by body composition

	Sedentary	Light	Moderate	Vigorous	Hard
MALES					
Normal weight (n=43)	927.9 (900.7, 955.0)	331.4 (311.6,351.2)	114.3 (103.9, 124.7)	39.1 (33.2, 44.9)	23.9 (18.1, 29.7)
Overweight (n=6)	902.5 (864.6, 940.4)	352.5 (295.0, 410.0)	122.3 (90.4, 154.1)	40.0 (27.6, 52.4)	23.9 (18.1, 29.7)
Obese (n=3)	1045.5 (933.8,1157.2)	255.5 (96.7, 414.3)	58.5 (38.3, 78.7)	14.0 (11.1, 16.9)	4.7 (0.7, 8.7)
Total (n=52)	935.1* (910.0, 960.2)	327.0 (307.8, 346.1)	110.5 ** (100.6, 120.4)	37.6 * (32.3, 42.9)	22.1 (16.9, 27.3)
FEMALES					
Normal weight (n=78)	962.8 (940.9, 984.7)	358.0 (328.6, 387.5)	96.6 (90.2, 103.4)	24.4 (22.0, 26.8)	12.7 (9.9, 15.5)
Overweight (n=8)	974.7 (943.6,1005.8)	355.4 (329.7, 381.2)	94.4 (80.4, 108.4)	24.2 (19.0, 29.4)	9.4 (5.1, 13.6)
Obese (n=4)	935.0 (795.3,1074.7)	370.3 (260.7, 479.8)	93.0 (73.6, 112.4)	28.8 (14.4, 43.2)	12.5 (1.1, 23.9)
Total (n=100)	963.8 (945.7, 981.9)	358.0 (344.6, 381.5)	96.1 (90.6, 101.6)	24.5 (22.3, 26.7)	12.1 (9.8, 14.4)

Significance for linear trend for body composition divisions-ANOVA

*P<0.05, ** P<0.01, *** P<0.001

5.3.5 Fitness data by gender and body composition grouping

Table 5.3 presents the data on cardio-respiratory fitness, estimated from the 20 MST by gender and body composition grouping. The difference between the body composition groupings was investigated and the significance in displayed in the final row.

Table 5.3. Means and 95% C.I. s of cardio-respiratory fitness data based on estimated VO_{2max} from the 20 MST

	VO _{2 max}
MALES	
Normal weight (n=43)	54.2 (52.8, 55.6)
Overweight (n=6)	50.5 (47.6, 53.4)
Obese (n=3)	46.6 (44.2, 49.0)
Total (n=52)	53.2 *** (51.8, 54.6)
FEMALES	
Normal weight (n=78)	49.9 (49.1, 50.7)
Overweight (n=8)	48.4 (47.2, 49.6)
Obese (n=4)	47.7 (44.1, 51.3)
Total (n=100)	49.5 (48.8, 50.2)

Significance for linear trend for body composition divisions-ANOVA

*P<0.05, ** P<0.01, *** P<0.001

5.3.6 Overall energy expenditure between genders

To examine activity of at least a vigorous level, the time for ‘vigorous’ and ‘hard’ activity were combined. This overall vigorous/hard activity score was 64.3 minutes in boys. The mean vigorous/hard activity score in girls was 37 minutes. There was a significant difference between the categories of body composition for boys and the time spent in vigorous activity (ANOVA linear trend P<0.03). The minutes spent in moderate intensity activity was 110.5 in

boys compared to 96.1 in girls and the difference was significant (P=0.007). The total activity energy expenditure per day was obtained for each subject and a significant difference between the genders in overall energy expended in daily physical activity was evident (mean boys 562.88 (512.5, 613.3), girls 453.4 (424.8, 481.96) (P<0.0001).

The issue of any difference between physical activity on week days and weekend days was investigated in those subjects who wore the accelerometer on equal days of each (n=38). There was no significant difference in the energy expended in the two week days compared to weekend days (930.7 kcal (858.9, 1002.5) and 809 (681.2, 936.8) respectively, P>0.05).

5.3.7 Correlations between body composition and activity, fitness

Table 5.4 Correlations between BMI z score, time in minutes spent sedentary, and in moderate, vigorous and hard activity, waist circumference and VO₂ max

Variable	Moderate mins	Hard mins	Vigorous mins	Sedentary mins	VO ₂ max
BMI z all	-0.14	-0.12	-0.06	0.05	-0.27**
BMI z m	-0.42**	-0.17	-0.25	0.22	-0.43**
BMI z f	0.07	-0.09	0.15	-0.06	-0.22**
Waist m	-0.47**	-0.09	-0.31*	0.33*	-0.50**
Waist f	-0.01	-0.54	-0.07	-0.01	-0.33**
VO2 max all	-	0.21**	0.23**	-0.12	-
VO2 max m	-	0.26	0.22	-0.14	-
VO2max f	-	-0.11	-0.10	-0.12	-

*P<0.05, ** P<0.01, *** P<0.001
m=males, f=females

Table 5.4 presents the correlations and level of significance between body composition (BMI as measured by z score and waist circumference), fitness and minutes spent in sedentary, light, moderate, vigorous and hard physical activity. The results suggest that there were significant positive correlations between waist circumference and time spent sedentary in boys ($P<0.05$), and time in both hard ($P<0.01$) and vigorous activity ($P<0.01$) and $VO_{2\text{ max}}$ in both genders. Significant negative correlations were found between time in vigorous activity and waist circumference in boys ($P<0.05$), but not girls, and this difference was found to be statistically significant ($P<0.05$). There were significant inverse correlations between $VO_{2\text{ max}}$ and waist circumference ($P<0.01$) and between $VO_{2\text{ max}}$ and BMI ($P<0.01$) in both boys and girls. Although it was not an objective of this study and was not powered for such, the association between fitness and time spent in moderate and vigorous activity was investigated and a significant relationship was found (Pearson correlation $r=0.22$, $P<0.01$).

5.3.8 Blood pressure

Table 5.5 details the descriptive data on systolic and diastolic blood pressure by gender and BMI status. There was no significant tendency for blood pressure between groupings for BMI in either gender. Table 5.6 presents the correlations and level of significance between blood pressure and time in minutes per day spent in moderate, vigorous and hard activity. The only significant finding was between systolic blood pressure and minutes in hard activity in the overall group ($P<0.05$).

Table 5.5: Means and 95% C.I. s of systolic and diastolic blood pressure in relation to gender and BMI status

Gender and BMI status	Systolic blood pressure mmHg	Diastolic blood pressure mmHg
Males normal weight (n=60)	109.4 (104.3-114.4)	69.8 (65.4-74.1)
Males overweight (n=10)	117.2 (109.3-125.2)	77.8 (69.8-85.8)
Males obese (n=7)	108.4 (95.0- 122.0)	67.9 (53.7-82.0)
Total males (n=77)	110.3 (106.1-114.4)	70.7 (67.0-74.3)
Females normal weight (n=102)	115.6 (111.5-119.7)	73.4 (69.2-77.5)
Females overweight (n=20)	120.0 (108.4- 131.7)	69.0 (60.6-77.4)
Females obese (n=7)	112.6 (97.3-127.9)	80.1 (69.8-90.5)
Total females (n=129)	116.1 (112.4-119.8)	73.1 (69.5-76.6)

Significance for linear trend for body composition divisions- ANOVA *P<0.05, ** P<0.01,

*** P<0.001

Table 5.6: Correlations between systolic and diastolic blood pressure and time spent in moderate, vigorous and hard activity (measured as r value in columns below with significance defined as * P<0.05, ** P<0.01, * P<0.001**

	Minutes in moderate activity	Minutes in vigorous activity	Minutes in hard activity
SBP all	-0.106	-0.165	-0.204*
DBP all	-0.101	-0.138	-0.092
SBP males	-0.198	-0.121	-0.267
DBP males	-0.029	-0.205	-0.088
SBP females	-0.034	-0.125	-0.111
DBP females	-0.126	-0.122	-0.102

5.3.9 Regression analysis

As the dependent variable in this study was body composition the regression analysis was done for BMI z score and for waist circumference. It is acknowledged that there was no normative data to develop z scores for waist circumference, but, as age was included and adjusted for, it was believed that the natural change with age would be accounted for. The different independent variables to predict waist circumference and BMI z score that were investigated were gender, age, minutes in moderate and vigorous (modvig) activity and fitness and blood pressure (both systolic and diastolic). As there was a correlation between minutes spent in sedentary activity and minutes spent in moderate and vigorous activity ($r=-0.62$, $P<0.001$) sedentary activity was not entered into the regression to avoid multicollinearity. As part of the regression analysis the distribution of BMI z score was analysed and found to be normal (one- sample Kolmogorov-Smirnov test found the test distribution to be normal, see Appendix 5)

Table 5.7 is a regression analysis using the dependent variables of both BMI z score and waist circumference and the independent variables of age, gender, fitness and minutes in moderate/vigorous physical activity.

Table 5.7 Regression analysis predicting body composition measures

Dependent variable	Age β and SE	Gender β and SE	Fitness β and SE	Modvig activity β and SE
BMI z	0.096 (.186)	-0.428 (.229)	-0.101 (0.024)***	-0.002 (0.002)
Waist	1.634 (1.036)	-3.144 (1.27)**	-0.741 (0.135)***	-0.019 (.011)

Significance * $P<0.05$, ** $P<0.01$, *** $P<0.001$

It was seen that waist circumference was predicted by fitness and gender (Table 5.7). As gender was found to predict waist circumference, a test for interaction with gender and fitness was performed (Table 5.8). The test for interaction was performed and, even though this did not show a significant difference between the genders, when minutes in moderate and vigorous activity was entered into the model (P= 0.06) separate regression analysis for the genders was performed with waist circumference as the dependent variable.

Table 5.8 Interaction with gender and fitness with waist circumference as the dependent variable

Dependent variable	age β and SE	fitness β and SE	gender β and SE	modvig activity β and SE	gender x fitness β and SE
waist cm	1.69 (1.02)	-1.5 (0.42)***	-29.13 (13.8)*	-0.015 (0.011)	0.51 (0.27) (P=0.06)

Table 5.9 and 5.10 are regression analyses predicting waist circumference in boys and girls separately and including age, systolic blood pressure and activity and fitness (the latter two separately). The genders were separated due to the marginal finding of some evidence that the effect of fitness in predicting body composition was different between genders (just short of significance P=0.06, table 5.8). Fitness and minutes in moderate and vigorous activity were not considered together to avoid the problems of multicollinearity.

Table 5.9 Regression analysis predicting waist circumference in boys including fitness and moderate/vigorous activity separately

Dependent variable	age β and SE	Systolic BP β and SE	Modvig act β and SE	fitness β and SE
Boys waist cm	4.46 (2.07)*	0.099 (0.07)	-0.046 (0.021)	
Boys waist cm	3.6 (1.2)	0.07 (0.04)		0.882 (0.149)***

Significance * P<0.05, ** P<0.01, *** P<0.001

Table 5.10: Regression analysis predicting waist circumference in girls including fitness and moderate/vigorous activity separately

Dependent variable	age	Systolic BP	Modvig act	fitness
Girls waist cm	-1.02 (1.4)	0.024 (0.031)	0.005 (0.016)	
Girls waist cm	0.519 (1.3)	-0.004 (0.029)		-0.575 (0.177)**

Significance * P<0.05, ** P<0.01, *** P<0.001

5.3.10 Time spent in at least moderate activity and numbers meeting recommendations

Boys spent a mean of 174.6 (SD 60.0) minutes in moderate and vigorous activity per day and girls spent 133.0 (SD 42.8) minutes in such activity. Using a t-test a significant difference between these was found (P<0.001).

It was found that only 2 of the total number of subjects were engaging in less than the recommendation, as defined by Strong *et al.*, (2005) of 60 minutes of at least moderate intensity activity per day, and therefore no comparison was made.

5.4 Discussion

5.4.1 Introduction

The objective measurement of physical activity utilising the RT3 permitted the measurement of time spent in different intensities of activity, as well as time spent sedentary, in a large random sample of subjects. To the author’s knowledge this is the first study to investigate the relationship between body composition and both time spent in various intensities of activity and fitness in children.

5.4.2 Body composition

The height, weight and BMI measures in this study were compared to 1990 British Growth references (Cole *et al.*, 1998). Although there are Irish growth references (Hoey *et al.*, 1987) these do not include waist circumference so, for consistency, the British standards were used. When height was compared to these standards it was found that 48% of subjects were above the 75th percentile. It would therefore appear that the present British Growth Standards, which are 15 years old, may be underestimating height and this conclusion is supported by other data from a UK study (Chinn and Rona, 2001).

Of the 224 children, 20.5% were found to be overweight and 6.3% were obese by BMI criteria. These figures are slightly higher than those for children of the same age in Poland and France: 15.4% of children in Poland were overweight and 3.6% were obese, with 18.1% overweight and 3.8% obese in France (Malecka-Tendera *et al.*, 2005). A recent publication from the 1970 British birth cohort study found that 4.3% of 10 year olds were obese (in 1980) and 16.3% of 30 year olds (in 2000) were obese (Viner *et al.*, 2006). Evidence from Viner *et al.* (2006) and this study suggest that use in children of BMI as the sole identifier may substantially underestimate the incidence of overweight. While 31% of the subjects in this study had a BMI above the 75th percentile, 76% had a waist circumference above the 75th percentile.

5.4.3 Physical activity and inactivity

For analysis physical activity was divided into minutes per day spent at different intensities. The results show that boys engaged in a mean 64.3 minutes of hard/vigorous activity per day whereas the mean time spent in vigorous/hard activity in girls was 37 minutes per day. Boys were found to spend more time in moderate and vigorous activity compared to girls but there was no difference between the genders in the time spent in hard activity or time spent

sedentary. It is difficult to directly compare these findings to those of other studies due to differences in the method of measurement of physical activity, but previous investigations have also found that overall activity and vigorous activity performed by girls is less than that by boys (Armstrong and Bray, 1991; Falgairette *et al.*, 1996). While an examination of any difference in physical activity between weekdays and weekend days was not an objective of the study it was found that there was no significant difference in the energy expenditure.

The examination of body composition and time spent in vigorous activity yielded interesting results. In boys there was a significant difference between the three divisions of body composition (normal, overweight and obese) and time spent in vigorous activity and a negative correlation between BMI and time spent in moderate activity. In girls, by contrast, there was no significant relationship between body composition and activity measures. This result is similar to a study in a younger age group where overweight boys were significantly less active than normal weight boys, but no differences were seen in girls (Trost *et al.*, 2003).

The correlation between waist circumference and activity also demonstrated gender differences. There were significant negative correlations between waist circumference and minutes spent in vigorous activity and moderate activity in boys but not in girls. Furthermore, a significant positive correlation between waist circumference and time spent sedentary was seen in boys only. However when the relationship was examined by regression analysis there was no relationship between waist circumference and physical activity in either gender. In this context, it is of interest that Rush *et al.* (2003) found physical activity to be inversely correlated with body fat in boys ($r=-0.43$, $P=0.006$) but not in girls.

5.4.4 Body composition and physical fitness

Physical fitness was higher overall in boys than girls, and in boys there was a significant difference between the three divisions of body composition and fitness. BMI- z scores were negatively correlated with fitness in both genders as was waist circumference and fitness. Although not an objective of the study, significant correlations between time spent in hard or vigorous activity and time in moderate and vigorous activity and fitness in both boys and girls was found. The findings that fitness is a predictor for waist circumference is of interest. It appears that there is no difference between the genders in terms of this interaction. In both boys and girls fitness appears to predict body composition (as measured by waist circumference).

5.4.5 Clinical implications of the findings

One of the clinical implications of these findings is that BMI alone has limitations in terms of assessing overweight and that relatively simple measures, such as waist circumference and perhaps fitness may give a clearer picture of health risk. Janssen *et al.* (2005) have provided additional evidence that a combination of BMI and waist circumference should be used to measure the presence of cardiovascular risk in children and adolescents. The high incidence of excessive waist circumference that was found in both genders is of concern since central fat carries a risk of metabolic consequences (Bjorntorp., 1997). As fitness is related to body composition in both genders, regular assessment of fitness of individuals should be encouraged in schools. The protective effect of physical activity and fitness on cardiovascular risk profile in children also needs further study. Recent studies reported that fit but obese children had levels of inflammatory parameters as low as lean, unfit children (Halle *et al.*, 2004) and that fitness was inversely correlated with the pro-inflammatory marker CRP in boys but not in girls (Issai *et al.*, 2003). This finding, together with the evidence from this

present study, suggests a difference between girls and boys in the effects of activity on body composition.

The findings reported in this thesis in relation to the amount of time spent in at least moderate intensity activity (boys greater than 114.8 minutes and girls greater than 96.6 minutes per day) in children of normal weight needs to be considered in light of recent work by Tudor-Locke *et al.* (2004). The aim of the latter study was to establish preliminary, criterion - referenced standards for physical activity in children related to healthy BMI (as indicated by international cut off points) and their results would suggest a requirement of 120 minutes of activity per day for girls and 150 minutes of activity per day for boys. The current international guidelines (of 1 hr of physical activity for both genders) may be insufficient. Such a possibility is supported both by the findings of Tudor-Locke *et al.* (2004) and those from a recent EYHS study (Andersen *et al.*, 2006). Andersen *et al.* (2006) performed a cross-sectional study of 1732 9 - and 15 - year olds to assess the association of objectively measured physical activity and clustering of cardiovascular disease risk factors. It was found that the odds ratio for having a clustered risk for ascending quintiles of physical activity was 3.29, 3.13 and 2.08 compared with the most active quintile. The mean time in moderate intensity activity in the fourth quintile was 116 minutes per day in the 9 year olds leading the authors to state that the guidelines should be higher than the current guideline of 60 minutes per day.

5.4.6 Limitations

Despite the value of accelerometers in the objective measurement of physical activity in children the high failure rate that occurred in this study emphasises the vulnerability of these units to subject interference and children forgetting to wear the device. It could be argued that the need for parental agreement and consent may have also led to bias, with those parents more committed to physical activity agreeing to their child's participation. This is a limitation

to any such study, and there was no way of determining if the children of parents who consented were any different to those who did not consent. A further limitation may be the use of the specific cut-off points for the definition of each activity intensity. However, while each band contains a large range of movement counts, it does permit some classification of activity which cannot be done with other physical activity measures.

5.5 Conclusion

Boys were found to engage in more than one hour of vigorous/hard daily physical activity, compared to girls who spent approximately half this time. In both genders fitness appears to predict body composition, as measured by waist circumference.

CHAPTER 6: OBJECTIVELY MEASURED PHYSICAL ACTIVITY IN CHILDREN WITH OBESITY (STUDY FOUR)

6.1 Introduction

In the previous study the association between physical activity and body composition in children aged 7-9.9 was examined. Rates of overweight and obesity of 20.5% and 6.3% respectively, were demonstrated, which are similar to EASO (2003) figures (see Figure 1.1, page 4). Furthermore, the study demonstrated a significant negative correlation between body composition and moderate/vigorous physical activity in boys but not in girls. However, activity was not found to predict body composition in either gender. Fitness was demonstrated to be an explanatory variable for waist circumference in both genders.

In Study three only fourteen children were obese, but activity was measured in only seven of these children (See Chapter 5, section 5.3.1, page 139). In terms of moderate activity, obese boys were spending significantly less time compared to non-obese boys. A similar pattern is evident for vigorous activity. In terms of time spent sedentary, obese boys were spending significantly more time than non-obese boys. These patterns were not seen in girls (see Chapter 5, Table 5.2, page 145). It is also interesting to note that the obese boys (n=3) were, on average, spending 58.5 minutes per day in moderate activity and obese girls (n=4) were, on average, engaged in 93.0 minutes of moderate activity. Therefore, obese boys were not achieving the minimal recommended level of 60 minutes per day of moderate activity, but obese girls were engaging in the minimal recommendation. The question therefore arises as to whether the activity levels of the small number of obese children in Study 3 were representative.

If children who are obese are achieving current activity recommendations one has to question whether current recommendations are sufficient. It is difficult to assess the

activity levels of obese children from the data of study 3 as the numbers were very small. The aim therefore of this study is to examine the activity patterns in a larger cohort of children with obesity.

The objectives were:

- To determine the time spent in moderate, vigorous and hard activity in children with obesity.
- To determine the number of children with obesity meeting current activity recommendations
- To compare physical activity levels in boys and girls with obesity

6.2 Methodology

6.2.1 Sampling and Subjects

The identification of a sample and an appropriate sampling method posed difficulties for this study. Based on the percentages of obese children in study three it was calculated that screening over 500 children would yield a sample of 32 children. The screening of 500 children to obtain data on 32 children would be wasteful in terms of time and resources on the part of the researcher. More importantly however, a large number of children would be subjected to unnecessary measurements in order to identify a small number of subjects.

A second issue also arises whereby children identified as obese would then have been invited to have their activity monitored. Realistically, the only logistical method of obtaining a large sample of children would have been through schools. Inviting children who were obese to have their activity measured would have singled them out in front of their peers, teachers and their families. Identifying children who were obese in this manner would not be psychologically beneficial to the children and one could argue that carrying out a study in such a manner would be unethical as it could be psychologically

damaging to the children, especially when children who are overweight or obese have low self esteem (Schwimmer *et al.*, 2003).

As using schools was not deemed appropriate other methods such as General Practitioner or Public Health Nurse referral, were considered. On further examination neither of these referral methods were deemed appropriate. In order to examine a population with a specific condition purposive sampling can be appropriate. To identify activity levels in children with obesity it was decided to recruit a purposive sample of children attending a weight management clinic. The children attending this clinic have been referred by General Practitioners, and other medical conditions that may be a reason for obesity have been excluded (e.g. Prader - Willi Syndrome). The weight management clinic in the National Children's Hospital in AMNCH was the only such clinic in Ireland at the time of this study.

A purposive sampling method was used which involved the recruitment of consecutive patients attending the weight reduction clinic in NCH over a specific time frame. The consultant Paediatricians were contacted and ethical approval was obtained from the Joint Research Ethics Committee of the St James's Hospital/ Adelaide and Meath incorporating the National Children's Hospital.

Subjects included consecutive new referrals to the Paediatric outpatient clinic in the National Children's Hospital, Tallaght, Dublin 24 between June 2005 and February 2006. The researcher attended the weekly clinic over the period to recruit subjects. Subjects with a learning disability were excluded because of the inherent limitations to physical activity due to their disability and possible inability to comprehend the instructions around the wearing of the RT3. The reason for including only new referrals was that the child needed to have activity measured prior to commencing an exercise programme as it was habitual activity that was of interest. Parents were approached and the aims of the

study were explained. If the child and parent were happy to participate, informed consent was obtained.

6.2.2 Measures

The RT3 accelerometer (Stayhealthy Inc, Monrovia, CA) was used for the objective measurement of physical activity. Activity was quantified in terms of minutes in light (VM: 100-970), moderate (VM: 970-2333), vigorous (VM: 2333-3500) (Rowlands *et al.*, 1999) and hard activity (VM: >3500) (Rowlands *et al.*, 2004).

Stature (standing height) was measured standing using a stadiometer (Holtain, Ltd) to the nearest mm. Weight was measured using SECA electronic scales, to the nearest 0.1kg. Body mass index (BMI) was computed as kg/m^2 . Waist circumference (to the nearest mm) was measured with a flexible non-stretchable tape measure at the level of the narrowest point between the lower costal border and the iliac crest (natural waist).

6.2.3 Procedure

Height, weight and waist circumference were measured. The accelerometer was shown to the child and parent and the instructions on wearing it explained. The RT3 was initialized and given to the child who was requested to wear it for 4 days. Four days of activity has been found to be a sufficient length of time to determine habitual activity levels in children (Trost *et al.*, 2000). The second visit for the child attending the clinic would have been one month later and therefore a padded SAE was given to the parent who was asked to return it by post. On return of the accelerometers, the data were downloaded to a lap-top computer and saved in Excel spreadsheets. The minutes in each intensity of activity were calculated for the four days, and the daily average of minutes spent in each intensity of activity were recorded.

6.2.3 Data analysis

BMI was compared to the British 1990 growth references and transferred to SDS (standard deviation) scores (Cole *et al.*, 1998). Activity was quantified as described above in 6.2.2. Descriptive analyses are presented for continuous data as means and confidence intervals, and the data are presented in graphs. Data was entered into Excel and SPSS and descriptive statistics are presented.

6.3 Results

6.3.1 Main findings

In the eight months between June 2005 and February 2006 data were obtained on 40 children (17 boys and 23 girls who returned the RT3 with data) attending the clinic in the NCH. These children wore the RT3 for 4 days in addition to having anthropometric measures performed.

Table 6.1 details the means and standard deviations for BMI, waist circumference and minutes spent in different intensities of activity for 40 subjects aged between 6 and 15 years. Table 6.2 details the minutes spent in the specific intensities of activity daily in both genders.

6.3.2 Number meeting current activity recommendations

When the activity levels of children in the study were compared to the recommendation of at least 60 minutes of moderate to vigorous activity per day, it was seen that 5 boys (29% of boys) and 7 girls (30% of girls) were engaging for less than the recommended time.

Table 6.1: Age, BMI and waist circumference of subjects, means and 95% C.I. s

Gender	Age	BMI z score	Waist cm
Boys (n=17)	10.9 (9.7, 12.1)	2.8 (2.6, 3.0)	95.6 (90.0, 101.2)
Girls (n=23)	10.7 (9.68, 11.7)	2.7 (2.5, 2.9)	93.0 (88.4, 97.6)

Table 6.2: Minutes per day spent in sedentary, moderate, vigorous and hard activity, means and 95% C.I.s

Gender	Sedentary	Moderate	Vigorous	Hard
Boys (n=17)	1074 (997.9, 1151.1)	71.5 (51.5, 81.3)	18.4 (8.6, 28.2)	13.9 (1.6, 26.4)
Girls (n=23)	1106 (1037.8, 1174.2)	51.1 (40.2, 67.7)	9.4 (6.4, 12.4)	2.2 (1.2, 3.2)

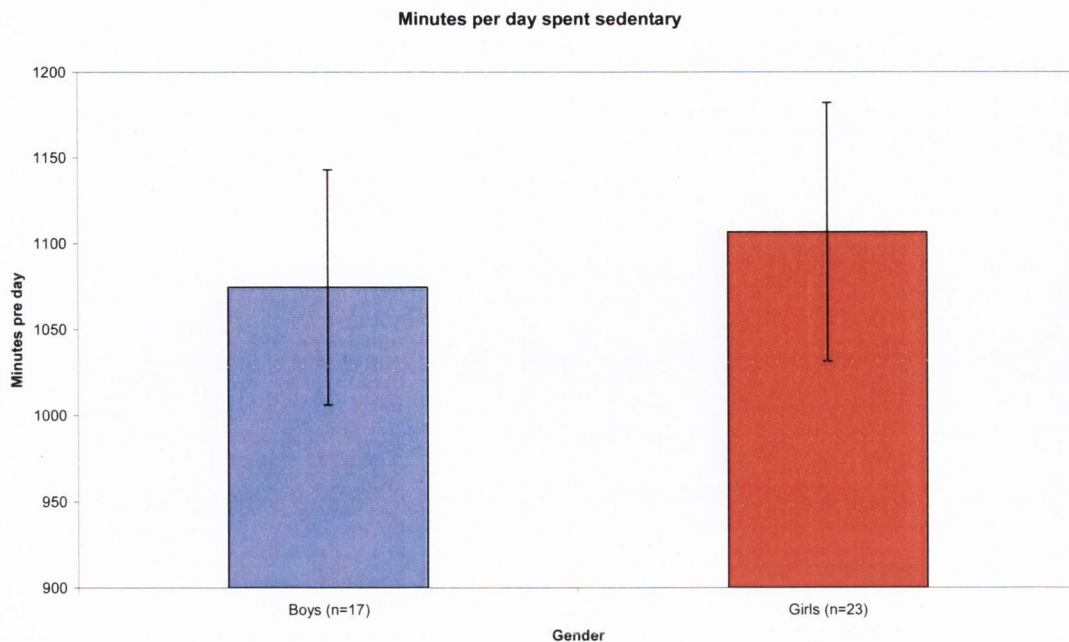


Figure 6.1 Minutes per day spent sedentary in children with obesity

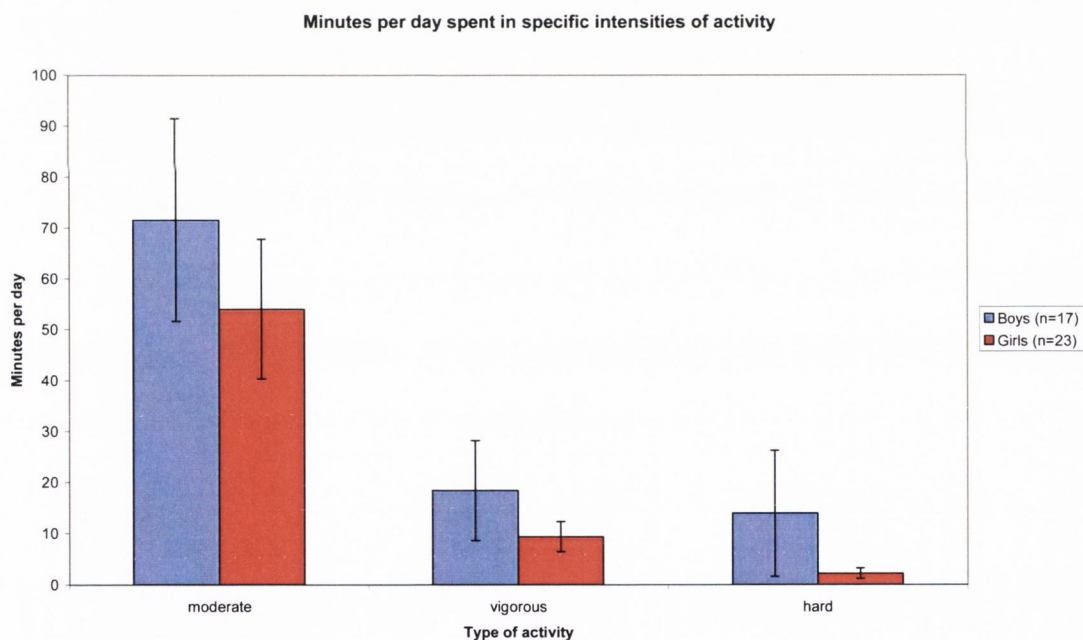


Figure 6.2 Minutes per day spent in different intensities of activity in children with obesity

6.3.3 Difference between boys and girls with obesity in terms of activity

The graphs in Figures 6.1 and 6.2 have detailed the mean time spent in the different intensities of activity in boys and girls with obesity. Unpaired t-tests (unequal variance) were performed, and there were no significant differences in the amount of time spent sedentary or in activities of different intensities.

6.4 Discussion

The most significant finding of this study was the very high amount of time spent sedentary in children with obesity in both genders. The mean number of minutes per day spent sedentary in boys who were obese was 1074 (997.9, 1151.1) minutes per day. Estimating that 840 minutes per day are necessarily sedentary due to sleep for 9 hours and sitting at school for 5 hours, then 840 minutes are fully accounted for. Therefore in boys who were obese, 236 minutes, or just under 4 hours, per day were spent sedentary. In girls who were obese the mean number of minutes sedentary was 1106 (1037.8, 1174.2) accounting for 266 minutes or 4.4 hours per day.

When the results of this study were compared to children in study three it can be seen that the obese subjects were spending considerably more time sedentary. In Study three the mean minutes spent sedentary by boys was 88 minutes (almost 1.5 hours) and by girls was 123 minutes (just over 2 hours).

Along with the increase in time sedentary, the time spent in both vigorous and hard activity in obese children was much lower than in the children in study three. Boys who were obese spent 18.4 and 13.9 minutes per day in vigorous and hard activity, respectively, compared to 39.1 and 23.9 in non-obese boys. In girls, these figures were 9.4 and 2.2 in obese compared to 24.4 and 12.7 in the non-obese. When the activity levels in this group of children were compared to the minimal recommendation of at least 60

minutes of moderate intensity activity per day, it was seen that 29% of boys and 30% of girls were failing to achieve such recommendations. In study three it was seen that all but 2 subjects of 152 (0.1%) were meeting current recommendations.

It is acknowledged that the two groups cannot be directly compared due to the different methods of sampling, the numbers and the age span in these studies. While the ideal method of sampling children with obesity would have been obtaining such subjects from the general population and a possible method of recruitment could have been through schools, this was not possible for ethical and logistical reasons. It was believed by the researcher that the knowledge gained would have had to outweigh the possible psychological difficulty associated with the research.

6.5 Conclusion

Children with obesity spent considerable time sedentary per day and little time engaged in moderate, vigorous and hard activity when compared to those of normal weight. Thirty percent were failing to meet the minimal activity recommendations.

CHAPTER 7: DISCUSSION AND FURTHER RESEARCH

7.1 Introduction and main findings

The central theme of this work was the question of the relationship between body composition and physical activity. This work was prompted by the increasing incidence of childhood obesity and its potential health consequences. The main objectives of the thesis were a determination of current physical activity levels in children; an examination of the numbers adhering to activity recommendations; and the relationship between body composition and both time spent in different intensities of activity, and fitness. The question of the ability of the RT3 accelerometer to measure physical activity in children was also posed.

At the time of the design of the investigations, there were no studies in the literature of large representative samples of children aged 7-10 years that had measured body composition and physical activity in terms of intensity. Therefore, the studies were original within the specific timeframe. It is of particular interest that, in the years following the design stage, a number of cross - sectional studies both from the European Youth Heart Study group and others, were published in this area (Ruiz *et al.*, 2006; Andersen *et al.*, 2006; Eklund *et al.*, 2004; Rennie *et al.*, 2005; Dencker *et al.*, 2006). Advances in technology which have permitted the measurement of different intensities of activity have been an important development that has facilitated such investigations. It is clear from this work that the use of accelerometers in measuring activity in children in large studies is possible and may add considerably to the understanding the dose-response of activity in relation to health parameters. The question of the number of children meeting current activity guidelines was one that had not been extensively studied at the time of the design of these studies. The lack of precision related to self report methods may have been a factor in this. However, it could also be argued that until the

epidemic of childhood obesity was evident, interest in the general area of body composition and activity was low.

Prior to discussing the specific findings reported here, it is important to highlight the validation of the measure used in determining physical activity. There were difficulties in quantifying overall activity and there was a need to find an objective measure that captured all activity, in addition to the intensity of activity. The challenges of measuring physical activity in children are detailed in Chapter 2 (pages 78-84). As a result of an extensive review of this literature, it was believed that the tri-axial accelerometer was the most appropriate method of measuring activity in young children. To measure habitual activity in children, a monitor that was lightweight and which would not interfere or influence regular activity was required. Furthermore a device that could differentiate between intensities was required so it was important to select a measure that could discriminate between intensities. Study two (Chapter 5) investigated whether the RT3 provided a valid measure of physical activity and found that it could accurately measure overall activity in addition to the intensity of activity.

The main findings of this thesis are outlined here. Activity did not predict body composition in either gender, but fitness did predict body composition, as assessed using the measurement of waist circumference. In correlational analysis body composition was inversely related to activity and positively related to inactivity in boys but not in girls. The results showed that boys engaged in a mean of 64.3 minutes of hard/vigorous activity per day, compared to girls who participated for a mean of 37 minutes per day in this level of activity ($P<0.001$). Boys also spent more time in moderate activity compared to girls (110.5 minutes and 96.1 minutes, respectively) ($P=0.007$) but no difference was found between the genders in time spent sedentary (935.1 and 963.8 minutes, respectively). Body composition was divided into three categories (normal, overweight and obese) and in boys there was a significant difference

between the categories in the time spent in moderate and vigorous activity. This was not seen in girls. While these results come from a study of cross-sectional design and therefore causality cannot be inferred, it must be acknowledged that others have produced somewhat similar findings since completion of this study. Trost *et al.* (2003) found that among pre-school children, overweight boys were significantly less active than their peers of normal weight but no such difference was seen in girls. Rush *et al.* (2003) found that lower levels of physical activity were associated with increased body fat in boys but not in girls.

In both genders, it was found that there was a relationship between body composition and fitness. It must be acknowledged that, while fitness is referred to throughout the thesis, it was only the parameter of cardiorespiratory capacity that was measured; the other parameters of fitness, such as muscle strength, flexibility and balance were not assessed. Although activity was not found to predict body composition in this study, it cannot be ignored. Fitness was found to predict body composition, and it is recognised that to achieve and maintain fitness, regular vigorous activity needs to be performed. In this study a relationship between vigorous activity and fitness in both genders was established, which supports other work in children aged 8-11 years where time spent in vigorous activity was correlated with VO_2 peak ($P < 0.05$ both genders) (Dencker *et al.*, 2006). If fitness helps to prevent obesity and the associated health consequences, it could be argued that activity recommendations should be designed to achieve fitness. Such recommendations would therefore require vigorous intensity activity to be included. It is acknowledged that, while a relationship between activity and fitness was found, the author is not claiming causality between the variables.

All but two subjects in Study three, where activity was measured objectively by accelerometry, were achieving the activity recommendations of 60 minutes of moderate to vigorous activity per day (Strong *et al.*, 2005). The lower end of this recommendation of 60 minutes of moderate

activity was achieved by almost all subjects. This finding was in stark contrast to the findings of Study one where, independent of which activity recommendation was used for comparison, considerable numbers appeared not to be achieving the recommendation (4% to 41 % in boys and 12% to 58% in girls, depending on which recommendation the levels were compared to).

Waist circumference was predicted by fitness in both genders but BMI was not. Measuring body composition poses many challenges as seen in chapter two. BMI is universally used as the method for determining and classifying overweight and obesity. However, one limitation in using BMI is that it cannot differentiate between fat mass and fat - free mass. Another limitation is that it provides no information on the distribution of body fat.

The above findings will now be considered in light of the questions posed and the methods used in this research. On the basis of the studies carried out there is a need to systematically review the methodology and the findings.

7.2 Analysis of methods used in this thesis

7.2.1 Is there a relationship between body composition and physical activity

The question of the relationship between body composition and activity has been explored in Chapter 1, section 1.2. While some of the results are conflicting, the consensus appears to be that a relationship may be seen in boys but not in girls. When Study three was designed there were few reports of research that had addressed the relationship between body composition and time spent in specific intensities of activity. Since then there have been a number of studies published in this area (Ruiz *et al.*, 2006; Rennie *et al.*, 2005; Eiberg *et al.*, 2005; Abbott and Davies, 2004).

The results of Study three indicate that there is a correlation between measures of body composition and activity in boys but not in girls. When subjects were grouped into categories of body composition, i.e. normal, overweight and obese, a significant linear trend was seen for time spent sedentary and negatively for time in moderate and vigorous activity in boys ($P<0.01$ and $P<0.05$ respectively). In contrast, there was no such trend in girls. In addition, significant negative correlations were seen between BMI z score and minutes in moderate activity in boys ($P<0.01$). There were also significant negative correlations between waist circumference and time spent in moderate and vigorous activity in boys ($P<0.01$ and $P<0.05$ respectively) and a positive correlation between waist circumference and time spent sedentary in boys ($P<0.05$). None of these relationships were seen in girls. However, it appears that activity cannot predict either BMI z score or waist circumference as, when the data were entered into a regression model with body composition as the dependent variable, neither time in sedentary or moderate/vigorous activity was significant.

In terms of a measurement used to determine body composition, BMI has limitations. It will be increased in those with excess body fat, but it may also be high in those with higher fat - free mass (i.e. muscle mass). Therefore, as a method of determining body composition, it has several limitations and may not have been the most appropriate measure. However, it remains the only standard means of classifying children in terms of normal, overweight and obese (Cole *et al.*, 2000).

Obese children demonstrated very high amounts of inactivity. The minutes per day spent sedentary in obese boys was 234 minutes (almost 4 hours) and in girls this figure was 266 minutes (4.3 hours) per day (see Chapter 6, Study four, page 163). These figures were considerably higher than those for non-obese children in Study three, where the time for boys was 95 minutes and for girls was 123 minutes (see page 145). These subjects cannot be directly

compared due to differences in sampling techniques, sample size and age distribution. Causality cannot be inferred from the results of Study four, and it could be argued that children were inactive because of their obesity. However, the results add to the findings from other studies (Trost *et al.*, 2003; Rush *et al.*, 2003), and it appears reasonable to suggest that restricting the time spent sedentary may be of considerable benefit to children with obesity. While activity does not appear to be an explanatory variable for body composition at this stage, there may be an association confounded by other variables, and the impact of activity on fitness needs to be acknowledged. Even if the contribution of activity to maintaining a healthy body composition is minor, it may be of considerable clinical importance, as it may be that small amounts of energy imbalance over time accumulate leading to an increase in body weight. Obesity may take months/years to develop and could be the result of a slight energy balance adjustment compounded over time. An increase in activity levels by a small amount, but performed every day may help to offset an increased calorie consumption or decreased energy expenditure due to such factors as motorized transport.

Regional fat distribution is different between the genders with boys carrying fat around the abdomen (android pattern) and the girls carrying fat around the hips (gynoid pattern) (Blaak, 2001). The health risks from increased fat deposited in the abdominal area are hyperinsulinemia, insulin resistance, hypercholesterolemia and atherosclerosis (Despres *et al.*, 1990). The distribution of fat is partly influenced by lipoprotein lipase (LPL). Stored lipid is the body's most plentiful source of energy and mostly found in adipose tissue. The hormonal release as a result of activity stimulates adipose tissue lipolysis which brings free fatty acids to the muscles involved in the specific activity (McArdle *et al.*, 1996). There may be a preferential reduction in the fat in the upper body and visceral fat with exercise training, compared to the more resistant fat around the hips. As seen in adults, in children (aged 11-16 years) the fatty acid composition of the abdominal adipose tissue comprises greater proportions of saturated

fatty acids and reduced monounsaturated and polyunsaturated fat, in comparison to fat around the hips (Mamalakis *et al.*, 2002). Therefore, it could be suggested that the effect of activity on body composition may be greater in men than women. However, this theory requires further examination, particularly in relation to pre-pubertal children. Interestingly in terms of weight loss, a meta-analysis of 53 studies concluded that men generally respond better to the weight-loss effect of exercise than women, and this may be due to the differences in fat distribution between the genders (Ballor and Keeseey, 1991).

In conclusion, there appears to be no definite relationship between body composition and activity in girls of this age. No definite relationship between body composition and activity was seen in boys but as the relationship was just short of significance it may be that the physiological response to exercise could be slightly different between the genders, but this requires further investigation.

7.2.2. Were children meeting current activity recommendations?

The activity data obtained by accelerometry in Study three was analysed in terms of minutes spent per day in specific intensities of activity. It was found that all but two subjects were meeting the current minimal recommendations of 60 minutes of moderate to vigorous physical activity per day. The method of measuring activity by accelerometry is very different to measuring activity by questionnaires as it captures all activity during the day. Physical activity data was obtained on 152 children in Study three and all but two were accumulating at least the minimal recommendation of 60 minutes of moderate intensity activity daily. However, in Study one, independent of which activity recommendation was used for comparison, there were considerable numbers who appeared not to be achieving the recommendation (14% to 41 % in boys and 24% to 58% in girls), depending on which recommendation the levels were compared to.

There appears, therefore, to be a dichotomy between Study one and Study three in terms of the numbers attaining activity recommendations. While there was a difference in terms of the timeframe of when both studies took place, this alone could not account for such a considerable difference. The authenticity of each of the measures used must be examined before accepting or rejecting either of the findings of the two studies. The studies were both performed in Second Class children in Dublin schools, but the method of measuring activity and the numbers studied were very different, so the design and sampling of each are examined to establish the confidence that can be attributed to the findings of each.

In Study three children generally were meeting current activity recommendations, and this raises some questions. The RT3 was found, in Study 2, to be a valid tool in measurement of inactivity and activity of varying intensities. The main limitations of the RT3 are the inability to measure water based activities and an underestimation of energy expenditure in uphill or isometric work. These limitations may have resulted in an overall under-representation of actual activity and therefore energy expenditure in overall activity may be greater than the values presented.

Despite the fact that the classifications used for determining intensity of activity was based on previous work in the area, it could be argued that some of what was considered moderate activity was actually light activity. Moderate intensity activity was classified as Vector Magnitude of 970-2333 and therefore the spectrum defined as moderate is reasonably wide. Walking at a pace of 3km/h resulted in a mean VM of 1973 (SD ± 261) and a VO_2 of 17 ± 4.2 ml/min, and it could be argued that activities at the lower end of the range that is defined as moderate could be considered of a light intensity.

In Study one, a large socioeconomic and geographical representative sample of children aged 7-9 was obtained, and therefore the findings of study cannot be attributed to a spurious sample. Activity was measured by a questionnaire which had been established in terms of validity and reliability, and, while limitations may be associated with reporting of activity in children, it was the only feasible means of measuring activity in the 10% sample of children in second class in National schools in the Dublin area. If the findings in Study one had been such that all subjects were meeting current recommendations then the direction of the work in this thesis might have been different. As a percentage of children were found to be engaging in less than recommended activity, there was a requirement to study this area further. The question of how well activity was measured by the questionnaire needs to be examined.

The questionnaire chosen, the “MAQA”, did ask questions on the number of times the child engages in 20 minutes of hard and light activity in the previous 14 days, as well as questions on the regular activities the child engaged in over the last year. The time spent sedentary in front of a screen was also requested. Therefore, it would appear that these domains of total daily activity were captured. The accuracy of the parental reporting could be questioned, and such a concern is related to data obtained from questionnaires in general. It could be argued that parents may have attempted to answer questions in a socially desirable manner, and this type of error could be comprehended in terms of the focus on activity and obesity in children over the past number of years. (Although this was not as much a media feature prior to the year 2000). However, if such an error was evident it could be argued that it should have been in the opposite direction, i.e. over-reporting of childrens’ activity by parents for reasons of social desirability.

The original MAQA contains a question on the involvement of the child in competitive sports and the level of such competition, in addition to the number of activities the child competed in.

This question was omitted due to the age group under investigation, as it was considered that at this age few would be involved to such a level. In older children who are involved in sport at this level, this question would provide additional data on regular activity which may significantly contribute to overall daily/weekly activity. This type of exercise is easier to document than the non-regular activity seen in young children.

The final question sought information on time and frequency of regular activities and from this question energy expenditure is calculated from MET values which are obtained from tables (Ainsworth *et al.*, 1993). The MET unit is defined as the energy expenditure of sitting quietly which is equivalent to a resting oxygen intake of 3.5 ml/kg/min. The Compendium of Physical Activities that was compiled by Ainsworth *et al.* (1993), was devised from adult data. This may not be appropriate for children as the energy cost for a child engaging in a specific activity may be greater due to higher resting energy expenditure and biomechanical differences such as leg length and the size of the muscle mass. Harrell *et al.* (2005) studied caloric cost and metabolic equivalents of activities commonly performed by children and adolescents, ranging from television watching to running or skipping. It was found that energy expenditure per kg body mass at rest or during exercise is greater in children than adults and therefore adjustment to the tables is required for pre-pubertal children. Harrell *et al.*, (2005) did state that the compendium could be used to estimate energy expenditure if adjustment for resting energy expenditure is made. This was not done for Study one, as such data were not available at the time of the Study. In addition, as the tool used to measure activity was a questionnaire, direct measures of body composition were not performed. The use of metabolic equivalents for all could be questioned as the original resting oxygen consumption came from an individual aged 40 years and weighing 70kg and therefore may not be applicable in children (Byrne *et al.*, 2005). Byrne *et al.* (2005) investigated resting energy expenditure and energy expenditure in walking at what they defined as moderate intensity of 5.6km/h. Their results indicated that body

composition accounted for a significant variance in resting oxygen consumption. Overweight subjects who walked at 5.6 km/h were found to have a MET value that was 22% higher than the compendium defined (mean of 4.6 compared to 3.8). Therefore as METs are used extensively to estimate the energy cost of activities, a correction factor for resting metabolic rate may be required. In light of the above findings of Harrell *et al.* (2005) and Byrne *et al.* (2005) there may be a need for further study in the area of MET values for common activities in children, in addition to the possible influence of age and body mass on these values. It could be argued that the MET values used in this study underestimated the actual energy expenditure in children and subjects may have been expending higher levels than the findings suggest.

Current activity recommendations in terms of intensity are described as moderate to vigorous activity. The definitions of each intensity of activity seems to be somewhat arbitrary, and clarification and examples may be required if recommendations are to be followed. For the purpose of analyzing the data in Study one, obtained in terms of the minimal recommendations, a MET value that was equal to moderate activity was required. This was taken as 4 METs, which may appear somewhat arbitrary, but it was believed by the researcher to be appropriate as it is the value used for “walking to work or class”. Generally a value of, or greater than, 6 METs is considered to be vigorous (Taylor *et al.*, 1978). So far in this discussion of Study one the general problems associated with questionnaires and the method of calculating MET values have been examined. There are two other concerns about the data obtained by the questionnaire.

Firstly it assumes that each child expends the same amount of energy for a given activity/sport. Examples of the classifications are soccer match (10 METs), soccer casual (7 METs). This assumes that all children playing a soccer match expend the same energy for a given time period. However, this is not the case as the energy expenditure of a goal keeper would be

different from a midfield player. The pace of the match could vary depending on weather conditions, the opposition, the child's motivation, and the child could be substituted and therefore may spend an amount of time on the sideline. The confidence in such a method of estimating energy expenditure may need to be somewhat guarded, particularly for team games where running and general effort may differ considerably among the team members. In the case of other activities, e.g. timed swimming laps, it may be more accurate as subjects perform a similar workload.

Secondly, there is a problem of analyzing data from the regular energy expenditure and comparing it to a daily recommendation. The questionnaire cannot capture spontaneous activity and some of these children may therefore have been considerably more active overall than the findings suggest. Unplanned and non-regular activity is not captured, and therefore accumulated daily activity may be under-reported when using a questionnaire to measure activity. In children of the age studied, much un-organised play can take place, if sufficient opportunity arises (e.g. in home/ garden/ playground with other children), and often this type of play results in activity of varying intensities, e.g. running, climbing, playing ball games. A child may participate in an amount of daily vigorous activity that cannot be documented in terms of regular activity, and so attain the minimal activity recommended, but the child may appear to fall short of current recommendations when their activity is analysed by questionnaire. The inability to capture such data is important when considering overall activity in children and is a major problem when obtaining activity data in children. It is probably less of a concern in adults who have more regular lifestyle/exercise behaviors which probably account for the majority of overall activity. While the questionnaire may be reliable and valid for the specifics that it measures, i.e. **regular** physical activity, it could be argued that it is not a valid measure for **overall** activity in children.

The limitations of using questionnaires to measure activity in children have been discussed and it can be seen that aspects of overall activity are not captured. Therefore the results may lead to an under representation of actual activity levels in children. It could be suggested that subjects were achieving higher activity levels, which may have been closer to the results achieved by accelerometry in Study three. In summary, with the potential for under-reporting of METs and the inability of the questionnaire to capture spontaneous activity, a higher proportion of children may have been reaching recommended activity levels than appeared from the data generated by Study one.

7.2.3. Is there a relationship between body composition and fitness?

In both genders it was found that there was a relationship between body composition and fitness. Fitness may be an explanatory variable for waist circumference in both genders, though caution needs to be applied as the design of the study was cross-sectional. In addition, a dose response relationship is evident from this work. However, while the question can be answered it does lead on to another, which is how much activity is required for fitness? As seen in Chapter 1, section 1.4, fitness depends on a number of factors, and these include genetic make up, age, gender, as well as type of exercise. While the first three are non-modifiable any changes in fitness are dependent on the type, intensity, duration and frequency of activity/exercise. As genetic factors will be different, it may be that one size will not fit all, i.e. the type of exercise training/ activity may need to be higher in some children than others, in order to maintain a healthy body composition. The issue if whether current recommendations are sufficient is addressed later in this Chapter. Levels of activity in the individual child may need to be titrated with the aim of achieving and maintaining a level of fitness associated with a healthy body composition. How to define what these levels of fitness are for each age band and gender needs to be explored. The practicalities of measuring fitness regularly in children are considerable and, unless such was part of the school programme, it would be difficult to monitor.

7.2.4 Can the RT3 accurately measure physical activity?

Study two investigated the validity of the RT3 and found that the RT3 could accurately measure activity, in addition to the intensity of activity. Therefore, it was believed to be an appropriate measure to examine physical activity levels. While there is probably no ideal measure of physical activity, a valid instrument minimizes the amount of systematic error by ensuring the measures capture the concepts of interest. The researcher believes the accelerometer is the best available for measuring all intensities of activity, in addition to inactivity. Because all activity, throughout the time the monitor is worn, is recorded, relatively small amounts of high intensity activity are counted, such as running up a stairs, or moving around the classroom.

The monitor is lightweight and does not interfere or influence activity patterns. It was believed to be fairly robust and that it could take the general “wear and tear” associated with childrens’ activity. The limitations in terms of measuring activity by accelerometry are the inability to measure water based activities, and the underestimation of uphill walking/running and activities requiring high amounts of isometric work. These limitations were considered and it was thought that such activities would only contribute to a small percentage of overall physical activity in children. There were a number of accelerometers returned with no data (n=72) due to children fiddling with the monitor and losing the data, and a number of monitors were lost or damaged. So while the monitor was able to detect the varying activity of children of this age, a limitation is that it can easily be tampered with, resulting in complete loss of data for the subject in question.

7.3 The findings of body composition, activity, fitness and blood pressure in the subjects studied

In Study three it was found that 20.5% of children were overweight and 6.3% were obese. In terms of waist circumference 76% of children were above the 75th percentile, in comparison to only 31% over the 75% percentile for BMI. Waist circumference may be a more useful clinical measure than BMI, as BMI does not indicate the amount of body fat or where fat is stored. In the UK, Mc Carthy *et al.* (2003) found that trends in waist circumference during the past 10-20 years have greatly exceeded BMI, particularly in girls. Measuring waist circumference in school medicals by public health practitioners may help identify children at risk of ill- health associated with excess central fat. While the number overweight is of concern in such a young age group, a recent study in Portugal found much higher figures in 8-10 years olds, where 42.7% were found to be overweight or obese (Mota *et al.*, 2006).

The data used for percentile charts probably needs to be reviewed as, in addition to the findings of BMI and waist circumference, children were taller than the normal distribution in the percentile charts. Forty eight percent of subjects had a height above the 75th percentile. Secular trends in height among children during 2 decades were investigated as part of the Bogalusa study, and Freedman *et al.* (2000) found that the mean height of schoolchildren aged 5-17 between 1973 and 1992 increased by 0.70 cm per decade. The trend was strongest in pre-adolescents aged 9-12 years. Due to the reported increase in height, weight and waist circumference in the last 15-20 years, the relevance of the percentile charts that are used clinically could be questioned. An argument could be made for charts to be redeveloped with new data, but this could “normalise” those overweight as the charts would move to the right. It has been suggested that BMI norms for children and adolescents should be created from selected subgroups that have higher physical fitness rather than the general population as to do

so would include those who were overweight in the reference population due to the secular increases in BMI (Chen *et al.*, 2002).

The consequences of childhood obesity are significant and may impact considerably on health care services and on the morbidity and mortality of subjects. From these studies it can be seen that children as young as 7-9.9 years do present with obesity, with 6% in this age group found to be obese.

There were no differences between the genders in the time spent in sedentary activities. In Study one, sixty percent of children were spending two to three hours per day in front of a screen. In Study three, sedentary time was measured objectively by the accelerometer. Comparing sedentary time by the two methods does present some challenges as the accelerometer captures all time sedentary, including sleep and time sitting at school or at home, whereas the questionnaire only records time watching television in terms of hours. Presuming that a child sleeps for 9 hours a day and spends 5 hours in school sitting then 840 minutes per day is of necessity, spent sedentary. When 840 minutes was subtracted from overall time sedentary the resultant time can be presumed to be spent television watching/ PC games as well as sitting for meals, homework and reading. Analysing the data in such a way leads to the finding in Study three that boys spent a mean of 95 minutes per day sedentary and girls spend a mean of 123 minutes sedentary. Study one found that 77% spent at least 2-3 hours per day in front of a screen.

Study four investigated physical activity in a group of children with obesity by the same means as Study three, and the findings were that in boys a mean of 71.5 minutes and in girls a mean of 51.0 minutes were spent in daily moderate intensity activity. When the mean time spent in vigorous and hard activity were investigated it was found that boys spent 18.4 and 13.9 minutes

for vigorous and hard activity and girls spent 9.4 and 2.2 minutes in such intensities. In the subjects in Study four 30% of boys and 29% of girls were not meeting minimal recommendations of 60 minutes of moderate to vigorous activity per day.

Obese children demonstrated very high amounts of inactivity. The minutes per day spent sedentary in obese boys was 234 minutes or almost 4 hours and in girls this figure was 266 minutes or 4.3 hours per day (see Study four, page 164). These figures were considerably higher than those for non-obese children in Study 3 where the time spent sedentary for boys was 95 minutes and for girls, 123 minutes (page 145). Ideally, the subjects with obesity would have been drawn from the general population of children through schools. In Study three only 6% were found to be obese and therefore an extensive search through schools would have been required to obtain a number of children to study. However of greater impact may have been the ethical issues that could have arisen from such a method of sampling (Chapter 6, page 159). Therefore, a purposive sample was obtained from the Paediatric clinic in AMNCH. The hypothesis was that high levels of inactivity and low levels of activity would be recorded in children with obesity. The findings confirmed this hypothesis, and considerably lower levels of all intensities of activity were seen compared to those of normal weight.

The mean fitness levels for boys in study three was 53.2 ml/kg/min and in girls it was 49.5 ml/kg/min. The results for fitness were similar to findings on Portuguese children and were higher than those found in 6-7 year olds in the study by Hansen *et al.* (2005). Hansen *et al.* (2005) found mean VO_2 was 48.5 ml/kg/min in boys and 44.8 ml/kg/min in girls whereas in Study three (page 146) values of 51.7 ml/kg/min were found in 7-8 year olds boys and 50.5 ml/kg/min in girls. However, it must be acknowledged that the methods of measurement were not the same, and subjects in Hansen's study were one year younger. Fitness was found to be related to body composition in both genders, but only to waist circumference when regression

analysis was performed. The association was seen for both BMI and waist circumference. In children with obesity, low levels of fitness were demonstrated in a related study (see Appendix 6). These findings suggest that promotion of fitness is important in children from this young age. Fitness appears to be protective against increased body fat in children, and, even in boys who are overweight, fitness is related to less body fat and lower CRP (Isasi *et al.*, 2003). Lower blood pressure has been demonstrated following exercise training programmes and there is some evidence of the link between fitness and higher HDL levels but not insulin sensitivity. Although no evidence exists of the effect of physical activity on morbidity and mortality data, there is evidence of the beneficial effect of physical activity on a number of individual cardiovascular risk factors (e.g. obesity, blood pressure, CRP).

Lower blood pressure has been demonstrated following exercise training programmes, as seen in Chapter 1, section 1.3. Blood pressure measures were 110.3 mmHg systolic and 70.7 mmHg diastolic for boys and 116.1 mm Hg systolic and 73.1 mmHg diastolic for girls. There was no significant difference in blood pressure between groupings for BMI in either gender. Additional cardiovascular factors that could have been measured include blood markers (lipids, insulin, inflammatory markers). While the study did obtain ethical permission from the relevant ethics committee, the schools did not consent to having bloods taken on site and thus the original study design needed to be modified to be acceptable.

It could be questioned if the number of children with high waist measurements and BMI is a cause for concern. Psarra *et al.* (2005) examined the short-term tracking of abdominal obesity in children aged 6-12 years at baseline who were followed up for 2 years. It was found that the tracking of body fat distribution was high ($r=0.69-0.86$, $P<0.01$). Children with high waist circumference and low cardio-respiratory fitness initially had an increased risk of being in the higher quartile for waist circumference two years later ($P<0.01$). This suggests that assessing

fitness is important in children, along with body composition, and due to the long term health consequences, treatment should be initiated as early as possible.

The consequences of childhood obesity are significant, and resulting morbidity may impact considerably on health care services. From these studies it can be seen that children as young as 7-9.9 years do present with obesity and 6% in this age group were found to be obese. It may be reasoned that activity and fitness levels should be measured in children as part of school medicals. However, the measurement of physical activity poses many challenges and may not be feasible in large numbers of subjects at regular intervals. In contrast the measurement of fitness is relatively easy and can be done with a number of subjects at the same time. On the basis of the results of this thesis it could be argued that, as well as being appropriate, it is more feasible and cost effective to measure fitness.

7.4 Are current activity guidelines sufficient?

As there is a relationship between body composition and fitness, the adequacy of the current recommendations will be explored. In terms of public health guidelines it is imperative that the recommendations are evidence - based. The most recent recommendations were drawn up by an expert group who identified and reviewed 850 papers in this area. Most of the intervention studies that formed part of the review were supervised moderate to vigorous activity interventions with a duration of 30-45 minutes and a frequency of 3 to 5 days per week. The conclusion was that “ School-age youth should participate daily in 60 minutes or more of moderate to vigorous physical activity that is developmentally appropriate, enjoyable, and involves a variety of activities” (Strong *et al.*, 2005). The strength of the evidence base for these recommendations is questionable. There is little evidence for a dose- response relation as most of the activity interventions were described as moderate to vigorous of 30-45 minutes. It

could be argued that the recommendations of Strong *et al.* (2005) of a minimum of 60 minutes of moderate to vigorous activity per day are too low, given that, while almost all achieved such a level, a percentage were overweight (20.7% of boys and 20.2% of girls). A study by the EYHS also posed the question of the percentage of children that were meeting current activity recommendations as measured by uni-axial accelerometers (Riddoch *et al.*, 2004). In children aged 9 years, 97.4% of boys and 97.6% of girls were meeting the recommendations, although this decreased in 15 year olds. Thus, as with Study three, almost all children were meeting guidelines and as a number of children in both studies were overweight, the question of the adequacy of the guidelines needs to be addressed. It appears that children spend more time than initially thought in moderate intensity activity and perhaps this is not enough.

It could also be suggested that boys need to do more activity and reduce the time sedentary for a given level of body composition. A recent paper supports such a stance. Tudor - Locke *et al.* (2004) recommended different amounts of activity for girls and boys based on data on activity levels collected by pedometer and cut off points for normal weight and overweight/obesity (Chapter 1, page 33). The selected cut-off points for 6-12 year old children were 12,000 steps per day for girls and 15,000 steps per day for boys. These figures would equate to approximately 120 minutes of activity per day for girls and 150 minutes of activity per day for boys. Therefore, it may be that requirements for boys and girls not only need to be higher but to be different, due to inherent physiological or behavioral differences in the genders.

The idea that there is a need in both genders to have higher activity recommendations is supported by Andersen *et al.* (2006) who found a higher level of activity was needed to prevent clustering of cardiovascular disease risk factors. The study was part of the European Youth Heart Study and it investigated the associations of objectively measured physical activity with systolic blood pressure, triglyceride, total cholesterol/HDL ratio, insulin resistance, sum of four

skin-folds and aerobic fitness. Subjects were categorised into quintiles of physical activity and the lowest three had a raised risk in all parameters. This cross-sectional study of over 1700 randomly selected 9 and 15 year olds found that the odds ratio for having clustered risk for ascending quintiles of physical activity (measured by accelerometry in counts per minute) was 3.29 (1.96-5.32), 3.13 (1.87-5.25), 2.51 (1.47-4.26) and 2.03 (1.18-3.50) respectively when compared to the most active quintile. The mean time spent above 2000 counts per minute (which represents walking at 4km/h) in the highest quintile was 167 minutes and in the fourth quintile it was 116 minutes for the 9 year old children. Subjects in the fourth and fifth quintile did not have raised risk in all analyses, whereas those in the other quintiles did (risk was defined as a score above 1 SD). These findings would suggest that 116 minutes per day of moderate intensity activity are required to prevent clustering of cardiovascular risk factors. The cut-off for moderate intensity activity of walking at 4km/h set by Anderson *et al.* (2006) was higher than the cut-off set in either of the studies for this thesis. The findings in this thesis of figures of time spent in at least moderate intensity activity in those of normal weight was 177.3 minutes per day in boys and 133.7 minutes per day in girls. Such figures are higher than those suggested by Anderson *et al.* (2006) but similar to those suggested by Tudor-Locke *et al.* (2004) (150 minutes in boys and 120 minutes in girls). However the sample studied was considerably smaller than in the study by Tudor-Locke and had a narrower age range. The findings of these studies in addition to the present one lend support to questioning the relevance of recommendations of activity that are the same for both genders. It may be that boys need to do more activity and reduce their time sedentary for a given level of body composition.

Another study from the EYHS group investigated the relationship between the intensity of physical activity and fitness and fatness in children aged 9-10 years, and the definitions used for moderate activity was 3-6 METs and over 6 was classified as vigorous (Ruiz *et al.*, 2006). It

was found that lower body fat was significantly associated with higher levels of vigorous activity, and those spending more than 40 minutes per day at such an intensity had significantly lower body fat than those spending 10-18 minutes at vigorous activity daily

In light of the findings of this and other recent studies, there appears to be a need to increase current activity guidelines. As fitness was found to be an explanatory variable in body composition, guidelines are needed to help children achieve and maintain a degree of fitness. As vigorous activity is required for fitness, the recommendations need to include an amount of daily vigorous activity. The issue of whether advice on restricting inactivity, e.g. time watching television, needs to be included in recommendations also requires consideration. A question that needs to be asked is what level of fitness is required for a healthy body composition? If this was known, then school - based exercise programmes could aim for children to achieve this level and could work towards this goal.

The issue of definitions of intensities of activity needs to be addressed. Current activity recommendations in children are described as moderate to vigorous activity. The definitions of each intensity of activity seems to be somewhat arbitrary, and clarification is required if recommendations are to be followed. There is a whole body of work that could address the issue of what is considered mild/light, moderate and vigorous/hard activity by parents and children. What one parent may consider to be moderate for their child may be vigorous to another. In adults, Duncan *et al.* (2001) investigated the ability of adults to estimate the intensity and duration of their activity. Close estimations of duration of activity were found, but the level of intensity could not be accurately estimated, and particularly moderate intensity activity tended to be overestimated.

7.5 How to increase activity levels

The results of Study three in addition to those by Tudor - Locke *et al.* (2004) and Anderson *et al.* (2006) indicate that higher levels of activity than currently recommended are required for healthy body composition. While exact figures have not been defined, it appears that two hours daily for girls and two and a half hours for boys are needed. If higher amounts of activity are required for healthy body composition, then how these could be achieved needs to be considered. If the premise that the guidelines for activity in children need to be increased to several hours of moderate to vigorous activity, which includes at least a certain number of minutes of vigorous activity, and a restriction imposed on the amount of time sedentary then there is a need to look at ways of how this could be reached. The question of how higher levels of activity could be achieved (including sufficient vigorous intensity activity to maintain fitness) needs to be discussed. It could be argued that individuals have responsibility for their own health, and the health of their children and therefore if guidelines are clear the individual should be responsible for finding the means of achieving them. On the other hand, policy changes may make it easier for all to achieve the recommendations.

The main focus of the classic paper by Geoffrey Rose (1985) titled “Sick individuals and sick populations” was that individual and population approaches to improving health are different and achieve different objectives. The individual strategy aims to reduce high risk and is therefore personal to the individual. The benefit to risk ratio is favorable to the individual. The individual approach in altering lifestyle is difficult, even in people highly motivated as it is an ongoing behavioural change that needs to be adhered to. In addition, parents may not be aware of the health consequences of childhood overweight and obesity, and therefore may not perceive their childrens’ behaviours to be in need of change. For success, parents may also need to alter their lifestyles to incorporate higher amounts of physical activity as parental exercise has been found to be positively associated with children’s extracurricular sport participation ($P<0.001$) and 1.6 km run/walk time ($P<0.001$) (Cleland *et al.*, 2005).

The population approach attempts to shift the distribution of exposure in a specific population and Rose believed that this approach was powerful. Mass exposure control, e.g. tobacco control, can become the social norm, and therefore changes may be easier to implement. It may be difficult to reach certain groups through educational and health promotion means. Whereas population approaches often give limited benefit to individuals, in the poorer socio-economic communities the individual approach may be ineffective. The prevalence of adverse risk factors are generally higher in areas of deprivation. Therefore, using only the individual approach can widen health inequality.

The environmental factors that promote overweight and obesity appear to be multi-factorial and multi - level and create other difficulties for the individual attempting to change lifestyle habits. Preventative strategies need to address these underlying determinants, and therefore a deeper understanding of the contribution of these to obesity levels is required. In addition to the increased choices of sedentary activities, such as TV, video and PC games, there are other reasons why children may be less active than required for health benefits. Concerns for security in children have led to a situation where children are driven to school and spend less time outside in unsupervised play. In Study one only 40% walked all the way to school. Walking 10-15 minutes at a vigorous pace to and from school would increase activity levels considerably in 33% of children who were driven to school.

How to achieve increases in activity in children poses many problems. Children need to be protected from adverse health consequences. Responsibility can lie at a societal or an individual level. It could be argued that a population approach may be preferable when trying to increase activity levels in children as at an individual level it is difficult to change behaviours (need for extensive education) (Doyle *et al.*, 2006). Such a population approach could be implemented

by incorporating one hour per day of vigorous activity in schools. This would guarantee that children achieved almost half of the daily requirement if recommendations were raised.

Strategic population approaches include water fluoridation, speed limits and traffic calming, compulsory immunization in schoolchildren and the smoking ban in public places. Opponents to such approaches claim the rights of the individual should be upheld. However, leaving the change to individually dependent approaches is not likely to achieve shifts in the population health needed. In terms of physical activity, increasing the frequency of physical education classes in schools would be an example of a population approach. If such was implemented time spent in vigorous activity could be performed by all during school days. PE curricula and instruction could also focus on the knowledge, attitudes, motor and behavioural skills that are required to adopt and maintain lifelong physical activity. It could be argued that PE is a curriculum subject as important as other junior cycle subjects in terms of child development. To halt the rapidly increasing rates of childhood obesity, it may be that policy and legislative approaches are required for sustained success of physical activity and dietary interventions. Local environmental changes, including traffic restriction and provision of public play areas and sporting facilities, may provide one way of promoting physical activity in children.

In a democratic society the individual has choices and the balance of this choice needs consideration. On the balance of the points above, it would appear that the population approach may be the method of increasing activity in children. Children and adolescents spend most of their waking hours at school, so the availability of regular physical activity in school, increasing the amount of daily PE, and full participation in PE are critical in achieving the population approach.

7.6 Critical analysis of this work

A cross-sectional survey is a survey of a population at a single point in time. Cross - sectional surveys are useful for determining the prevalence of risk factors and the frequency of prevalent cases of a disease for a defined population. They can be useful in measuring current health status and planning health services. The major disadvantage of using cross-sectional surveys is that the data on both exposure to risk factors and presence or absence of disease are collected simultaneously, which creates problems in determining the temporal relationship of a presumed cause and effect. In terms of body composition and activity, it could be argued that children who are overweight are less active as a consequence of their body mass and, as a result of low activity levels, fitness could then be affected. If a child is overweight he/she may feel self conscious in terms of exercising with those of normal weight, and thus low fitness may be a consequence rather than a cause of increased body composition. Subjects in Study three were aged 7-9.9 years, and therefore it was believed at the outset that they had a number of years prior to puberty. Recent figures on pubertal age in Irish children were not found but studies in other countries suggest that the timing is between 10.7 and 11.2 years in girls with menarche occurring between 13.1 and 13.5 years (Parent et al, 2003). In a recent study in Turkish boys the mean age of onset of puberty was 11.6 ± 1.2 years (Bundak *et al.*, 2006). It could be argued that a small number of children could have had early pubertal onset which would have been associated with increased central fat, as early pubertal onset predicts central fat distribution (Kindblom *et al.*, 2006). However, in this study this appears to be unlikely as there were only 20 subjects aged 9 years or more.

To date there are a number of cross - sectional studies that have been performed in this area, and the results suggest an association between body composition and physical activity. It is not possible to determine a temporal relationship between activity and body composition, as it could be argued that those with higher body mass exercised less. Without information on

temporal relationships it is conceivable that changes in body composition could have occurred as a result of another risk factor. If it turns out that the exposure does not precede the development of the disease, the association cannot reflect a causal relationship. So while a cross sectional survey can be suggestive of possible risk factors, cohort and/or case - control studies are required to establish etiologic relationships. Cohort studies analyse changes over time in a group of people who have been subjected to different risk factors but who were initially disease free. This would be very difficult to do in children due to the problems associated with follow up over a prolonged time period and, as discussed earlier, the difficulties in measuring all the dimensions of physical activity in an objective manner. Ideally, randomised controlled trials with sufficient numbers of subjects, blinding of assessors and standardised methods of measurement are the best evidence for a cause and effect relationship. Randomisation is used as a means of equally distributing unknown confounding factors that have not been identified. Such a design would not be possible in a study investigating specific volumes of activity and body composition in children, and it could be unethical to restrict activity in one group. Logistically, it would be impossible as naturally occurring physical activity is an inherently unstable behaviour and as seen in Chapter 1, section 1.4 is influenced by many variables that could not be controlled in a real life situation.

Ideally, measures of blood cholesterol and glucose would have been taken and investigated in relation to activity, fitness and body composition in Study three. However while this was planned as part of Study three initially it was not possible to perform due to the considerable concern expressed by schools in relation to blood samples being taken in the school setting. The use of the 20-MST could be criticized due to the relative immaturity of children of this age from a biomechanical point of view. Motivation may also be a factor in the child exerting himself/herself as much as possible. However, children did not appear to have any difficulty in participating in the running test, and such a test would be the only feasible way to measure a

number of subjects at one point in time. In terms of motivation, it could be argued that in single tests the motivation of peers is lacking

One could suggest that there may have been a school or parental bias in Studies one and three. In respect to a schools bias, it is possible that the principals or boards who agreed for their school to participate did so as the activity/sport ethos was high compared to others. It could also be argued that, within schools, parents who encouraged their children to participate in sport and activity were those who consented for their child to participate in the study. To some degree these arguments could also be considered for Study one but the main difference was the involvement for the child was much greater in Study three where the objective measures were performed. However, this is a limitation of all studies and cannot be overcome where informed consent is required for participation.

7.7 Future research

A number of avenues of potential further research have been explored in the discussion. While it has been well recognised that there are many limitations to the use of questionnaires in the measurement of physical activity in children, they may be the only possible method in retrospective data collection. Therefore while they have limitations in measuring overall activity, regular activity may be captured by such means. The question of the relevance of specific MET values in children needs to be further explored, and there is a case to be made for compiling such data in children of normal weight and in those overweight. Newer methods of portable indirect calorimetry would facilitate such studies, as field based rather than simulated laboratory activities could be analysed.

There is a need to determine the optimal levels of fitness for healthy body composition in both genders and for each age group. The level and intensity of activity required for fitness needs to

be investigated, so that appropriate activity guidelines can be established for children. The possible differences in boys and girls regarding the activity required for fitness and thus health body composition needs consideration. This could begin with work similar to that by Tudor-Locke *et al.* (2004) where the question of how fit children need to be could emerge from criterion-referenced standards for healthy body composition using international cut off points. As waist circumference has been found to be related to cardiovascular and metabolic health consequences the use of criterion-referenced standards for this measure appears to be appropriate.

One of Hill's criteria for defining a risk factor is the reversal of such with change (Hill, 1965). The link between body composition and fitness could be tested by studying the effect of intense exercise programmes (which incorporate vigorous activity) which would increase fitness on body composition. Such studies could be done in children with obesity so that the effect on body composition could be evaluated. These would take a prolonged time period as such a study has been powered based on pilot work at 38 in each group and would therefore require considerable resources in terms of time and personnel (for sufficient supervision of children exercising at a high level) but could be examined in time.

The fact that children are taller and heavier than normative data leads on to the question of whether these standards need to be revised. The danger of "normalising" overweight would need to be addressed. Normative data for waist circumference is also needed for different ages and racial background.

7.8 Conclusion

A major problem in the study of activity levels in children is the question of how much activity is required for health and fitness benefits and how the different intensities of activity are

determined. Guidelines have changed over the years and the current ones appear to need to be increased in light of the findings of this and other related studies and the epidemic of childhood obesity.

In children aged 7-9.9 years, no direct relationship between body composition and activity was found, but there was a relationship between waist circumference and fitness. Physical activity levels were higher in boys than girls. This was confirmed by both subjective and objective measures. The fact that most children were meeting current recommendations yet a number were overweight suggests that recommendations need to be higher, as in order to achieve fitness, sufficient activity levels that incorporate time in vigorous activity are required. Children with obesity had low levels of activity and high levels of inactivity when compared to those of normal weight. The limitations of cross-sectional studies have been addressed.

The RT3 was investigated and was found to be a valid measure of physical activity and inactivity in children aged 7-12 years. A number of monitors were returned with no data due probably to the child disconnecting the battery and therefore the design may need to be improved to become more “tamper proof” for use by children. The main finding of this thesis was that fitness is an explanatory variable in body composition. The next question is how fit do children need to be for a healthy body composition and how do children reach such levels?

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APPENDICES

Appendix 1

For the calculation of $\text{VO}_{2\text{max}}$ (Leger and Lambert, 1982)

$$\text{VO}_{2\text{max}} = 31.025 + 3.238 \times \text{speed} - 3.248 \times \text{age} + 0.1536 \times \text{speed} \times \text{age}.$$

Appendix 2: Modifiable Activity Questionnaire for
Adolescents (Aaron et al, 1993)

Modifiable Activity Questionnaire for Adolescents

Activity component(s) assessed:
Leisure
Time frame of recall:
Past-year
Original mode of administration:
Self-administered with supervision
Primary source of information:
Dr. Deborah J. Aaron and Dr. Andrea M. Kriska
Department of Epidemiology
University of Pittsburgh
Pittsburgh, PA 15261



Primary references:
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Note: This questionnaire was adapted from the original Modifiable Activity Questionnaire described earlier in this publication (5,6).

RELIABILITY AND VALIDITY STUDIES

TABLE 34. Reliability studies of the Modifiable Activity Questionnaire for Adolescents.

Reference	Methods	Sample	Summary Results	
Aaron et al. (2)	Relationship between first test and 1-mo and 1-yr retest (Spearman correlations)	100 junior high school students (83% White)	1-mo	
			Males	
			h/wk	0.78*
			MET-h/wk	0.78*
			VIG-h/wk†	0.73*
			Females	
			h/wk	0.75*
			MET-h/wk	0.79*
			VIG-h/wk	0.87*
			1-yr	
			Males	
			h/wk	0.54*
			MET-h/wk	0.54*
			VIG-h/wk	0.48*
			Females	
			h/wk	0.65*
			MET-h/wk	0.71*
			VIG-h/wk	0.61*

* P < 0.05.
† Hours per week spent in vigorous activity.

TABLE 35. Validation studies of the Modifiable Activity Questionnaire for Adolescents.

Reference	Methods	Sample	Summary Results	
Aaron et al. (2)	Relationships between past-year questionnaire and average of four past-week questionnaires (Spearman correlations);	100 junior high school students between the ages of 15 and 18 yr (83% White)	Males	
			h/wk	0.55*
			MET-h/wk	0.57*
			VIG-h/wk†	0.67*
			Females	
			h/wk	0.82*
			MET-h/wk	0.83*
			VIG-h/wk	0.73*
			Percent agreement between reported sports participation and interscholastic rosters	
			Fall	100%
			Winter	86%
			Spring	95%

* P < 0.05.
† Hours per week spent in vigorous activity.

Modifiable Activity Questionnaire for Adolescents

DATE _____ NAME _____ ID _____

SCHOOL _____ CLASS _____

1. How many times in the past 14 days have you done at least 20 minutes of exercise hard enough to make you breathe heavily and make your heart beat fast? (Hard exercise includes, for example, playing basketball, jogging, or fast bicycling; include time in physical education class)

☐ None
☐ 1 to 2 days
☒ 3 to 5 days
☐ 6 to 8 days
☐ 9 or more days

2. How many times in the past 14 days have you done at least 20 minutes of light exercise that was not hard enough to make you breathe heavily and make your heart beat fast? (Light exercise includes playing basketball, walking or slow bicycling; include time in physical education class)

☐ None
☒ 1 to 2 days
☐ 3 to 5 days
☐ 6 to 8 days
☐ 9 or more days

3. During a normal week how many hours a day do you watch television and videos, or play computer or video games before or after school?

☐ None
☐ 1 hour or less
☐ 2 to 3 hours
☐ 4 to 5 hours
☐ 6 or more hours

4. During the past 12 months, how many team or individual sports or activities did you participate in on a competitive level, such as varsity or junior varsity sports, intramurals, or out-of-school programs.

☐ None
☐ 1 activity
☐ 2 activities
☐ 3 activities
☐ 4 or more activities

What activities did you compete in?

PAST YEAR LEISURE-TIME PHYSICAL ACTIVITY

Check all activities that you did at least 10 times in the **PAST YEAR**. Do not include time spent in school physical education classes. Make sure you include all sport teams that you participated in during the Last year.

- | | | |
|------------------|----------------------|-------------------------------|
| Aerobics | Gymnastics | Swimming (Laps) |
| Band/Drill Team | Hiking | Tennis |
| Baseball | Ice Skating | Volleyball |
| Basketball | Roller Skating | Water Skiing |
| Bicycling | Running for Exercise | Weight Training (Competitive) |
| Bowling | Skateboarding | Wrestling |
| Cheerleading | Snow Skiing | Others: |
| Dance Class | Soccer | _____ |
| Football | Softball | _____ |
| Garden/Yard Work | Street Hockey | _____ |

List each activity that you checked above in the "Activity" box below.

Check the months you did each activity and then estimate the amount of time spent in each activity.

Activity	J a n	F e b	M a r	A p r	M a y	J u n	J u l	A u g	S e p	O c t	N o v	D e c	Months per Year	Days Per Week	Minutes Per Day

INSTRUCTIONS

If the Questionnaire is being interviewer-administered, the interviewer first reads through the list of activities provided. The participant is instructed to identify all leisure activities from this list in which he/she participated at least 10 times in the past year (as the interviewer checks all positive responses). After the list has been read and all of the positive responses have been checked, the interviewer writes down each activity that was checked in the "Activity" column provided. Estimates of frequency and duration are then obtained for each of these activities. Specifically, for each activity, the months that the activity was performed over the past year (past 12 mo) is checked, and then the average number of days per week and the average minutes per day is entered in the appropriate columns. The participant also responds to four multiple choice questions that assess "hard and light exercise" over the past 2 wk, daily television watching, and competitive athletic participation. These questions were adapted from the Youth Risk Behavior Survey (4), which is described elsewhere in this document.

CALCULATIONS

1. Past year: (mo) $\times$ (4.3 wk/mo) $\times$ (days/wk) $\times$ (min/day) $\div$ (60 min/h) $\div$ (52 wk/yr) = h/wk averaged over the past year

The hours per week of all activities are summed to determine total past-year hours per week. This estimate can also be weighted by its estimated metabolic cost and expressed as MET-h per week by multiplying hours per week for each specific activity by the estimated MET value.

EXAMPLE

TABLE 36. Hypothetical data from the Modifiable Activity Questionnaire for adolescents.

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mo/yr	D/wk	Min/d
Soccer					✓	✓	✓	✓	✓				5	5	90
Basketball	✓	✓	✓							✓	✓	✓	6	5	120

Soccer:

$$(5 \text{ mo}) \times (5 \text{ days/wk}) \times (4.3 \text{ wk/mo}) \times (90 \text{ min/day}) \div (60 \text{ min/h}) \div (52 \text{ wk/y}) = 3.1 \text{ h/wk}$$

Basketball:

$$(6 \text{ mo}) \times (5 \text{ days/wk}) \times (4.3 \text{ wk/mo}) \times (120 \text{ min/day}) \div (60 \text{ min/h}) \div (52 \text{ wk/y}) = 5.0 \text{ h/wk}$$

$$\text{Total year leisure activity} = 3.1 \text{ h/wk} + 5.0 \text{ h/wk} = 8.1 \text{ h/wk}$$

Conversion to MET-h/wk:

$$\text{Soccer: } 3.1 \text{ h/wk} \times 7.5 \text{ METs} = 23.3 \text{ MET-h/wk}$$

$$\text{Basketball: } 5.0 \text{ h/wk} \times 9.0 \text{ METs} = 45.0 \text{ MET-h/wk}$$

$$\text{Total past-year leisure activity} = 23.3 \text{ MET-h/wk} + 45.0 \text{ MET-h/wk} = 68.3 \text{ MET-h/wk}$$

OTHER STUDIES USING THE QUESTIONNAIRE

In addition to the references cited, another study has used the MAQ for Adolescents Questionnaire (3).

REFERENCES

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Appendix 3: Modified version of Modifiable Activity
Questionnaire for Adolescents

School: _____

ID No: _____

Confidential Questionnaire
Activity levels in primary school children

Child's Name: _____

Date: _____

1. How many times in the past **14 days** has your child done at least **20** minutes of exercise hard enough to make them breathe heavily and make their heart beat fast? (Hard exercise includes, for example, playing soccer, camogie, gaelic football, jogging or fast bicycling; include time spent in physical education class).

- ☐ None
- ☐ 1 to 2 days
- ☐ 3 to 5 days
- ☐ 6 to 8 days
- ☐ 9 or more days

2. How many times in the past **14 days** has your child done at least **20** minutes of light exercise that was not hard enough to make your child breathe heavily and make their heart beat fast? (Light exercise includes playing games with friends, going for walks, bicycling near home, include time in physical education class).

- ☐ None
- ☐ 1 to 2 days
- ☐ 3 to 5 days
- ☐ 6 to 8 days
- ☐ 9 or more days

3. During a normal week how many hours a day does your child watch television and videos or play computer or video games (play station/ gameboy) before or after school?

- ☐ None
- ☐ 1 to 2 hours
- ☐ 3 to 5 hours
- ☐ 6 to 8 hours
- ☐ 9 or more hours

4. A. Does your child walk to and from school?

- ☐ Yes
- ☐ No
- ☐ Sometimes/ Occasionally

4. B. Does your child cycle to and from school?

- ☐ Yes
- ☐ No
- ☐ Sometimes/ Occasionally

5. Tick all activities that your child did at least 10 times in the PAST YEAR. Do **not** include time spent in school physical education classes. Make sure you include all sport teams that your child participated in during the last year.

Basketball	Gymnastics	Swimming (laps)
Bicycling	Hurling	Swimming (free swim)
Ballet	Rollerblading	Others:
Camogie	Running for exercise	_____
Dance classes	Skateboarding	_____
Gaelic Football	Soccer/ Football	_____

6. List each activity that you have ticked above in the “Activity” box below. Tick the months your child did each activity and then estimate to the best of your ability the amount of time spent in each activity.

Activity	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Months Per year	Days Per Week	Minutes Per Day

Appendix 4: Letter to parents informing them of Study 3.

26th September 2005

Activity Study in Schoolchildren

Dear Parent/ Guardian,

I am writing to request that you and your child consider participating in a research study on activity levels in children and how they relate to fitness, body composition and risk factors for disease.

A recent survey which examined levels of physical activity in Dublin schoolchildren suggested they are not taking the volume of physical activity necessary to benefit the cardiovascular system. However, the study had certain limitations such as; the parents gave their perception of the child's activities and the study was unable to measure the child's activity during non-organised play. During this study it is intended to use a small lightweight device worn on the waistband to measure physical activity called an accelerometer (similar in size and principle to a pedometer).

The study involves measuring height, weight, waist and hip circumferences, blood pressure and activity levels. Fitness will be measured by the shuttle running test (also known as the bleep test). This is often done in schools by P.E. teachers and a number of children may be familiar with it. Activity levels will be measured by means of a questionnaire completed by parents/ guardians and the child wearing an accelerometer for 4 days.

If you and your child were to agree to participate in this study we would ask you to read and sign the accompanying consent forms. There are two copies, one for yourself and your child (titled "Your Copy") and the others (titled "Teacher's Copy") to be returned to your child's teacher in the provided envelope.

Please find included further background information. If you have any further queries or concerns please do not hesitate to contact Juliette at 01-6082110/ jmhussey@tcd.ie. James O'Dwyer is also contactable on 086-8237565/ jjodwyer@tcd.ie to answer any questions.

Thank you for your participation,

Juliette Hussey
Acting Head

Appendix 5: BMI-SDS normality of data

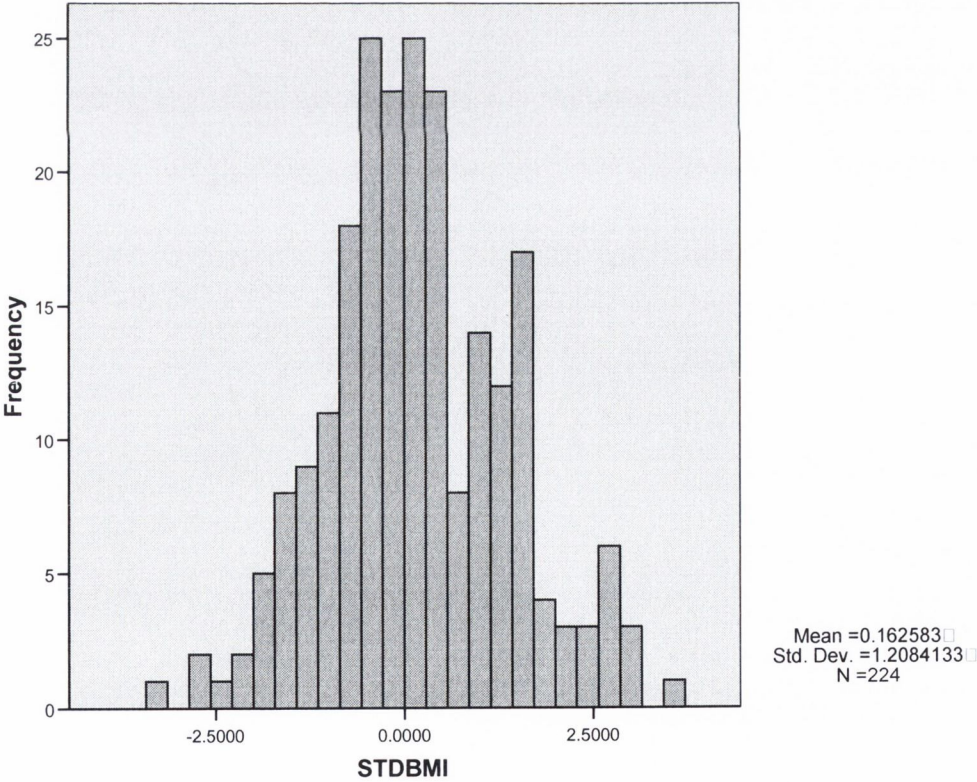
Appendix 5

Normality of BMI SDS data

One-Sample Kolmogorov-Smirnov Test

			STDBMI
N			224
Normal Parameters ^{a,b}	Mean		.162583
	Std. Deviation		1.2084133
Most Extreme Differences	Absolute		.059
	Positive		.059
	Negative		-.029
Kolmogorov-Smirnov Z			.887
Asymp. Sig. (2-tailed)			.411

- a. Test distribution is Normal.
- b. Calculated from data.



Appendix 6: Exercise tolerance in children referred to a weight reduction clinic and resulting publication

Appendix 6: EXERCISE TOLERANCE IN CHILDREN REFERRED TO A WEIGHT REDUCTION CLINIC

8.1 Introduction

In chapter one the problem of childhood obesity was presented. The literature regarding body composition and physical fitness was presented in Chapter 1, sections 1.2 and 1.3. In adults low levels of both fitness and activity have been identified as cardiovascular risk factors (Lee *et al.*, 1999; Blair *et al.*, 1999). There would appear to be a protective effect of physical activity and fitness on cardiovascular risk profile in children with obesity. A recent study in children found that those who were obese but fit has similar levels of inflammatory parameters as lean unfit children indicating that fitness counteracts inflammation associated with obesity (Halle *et al.*, 2004). Fitness has also been found to be inversely correlated to CRP (an inflammatory marker) in boys ($P < 0.01$) (Issai *et al.*, 2003), and high levels of physical activity have been found to be associated with favourable lipid profiles in children and adolescents (Suter and Hawes, 1993; Friedland *et al.*, 2005). Study three examined activity and fitness levels in children aged 7-9 years and found that fitness was an explanatory variable in predicting body composition. However within the sample studied there were only 6% classified as obese. This study aimed to investigate fitness and physical activity in children with obesity.

The aim of this study was to determine physical activity levels and exercise tolerance in children with exogenous obesity.

8.2 Methods

8.2.1 Sampling

The method of sampling in this study was the same as for study four for the same reasons. In order to identify activity levels in children with obesity it was decided to recruit a purposive

sample of children attending a weight management clinic. In order to examine a population with a specific condition purposive sampling can be appropriate. The children attending this clinic have been referred by General Practitioners and other medical conditions that may be a reason for obesity have been excluded (e.g. Prader Willi Syndrome). The weight management clinic in the National Children's Hospital in AMNCH was the only such clinic in Ireland at the time of this study. The consultant Paediatricians were contacted and ethical approval was obtained from the Joint Research Ethics Committee of the St James's Hospital/ Adelaide and Meath incorporating the National Children's Hospital.

Subjects included those aged 6-16 years with no major limitation to physical activity. Consecutive new referrals to the Paediatric outpatient clinic in the National Children's Hospital, Tallaght, Dublin 24 between September 2002 and June 2004 were approached by the researcher who attended the weekly clinic over the period to recruit subjects. Subjects with a learning disability were excluded due to the inherent limitations to physical activity due to their disability and possible inability to comprehend the instructions of the test. The reason including only new referrals was that the child needed to have fitness measured prior to commencing an exercise programme. Parents were approached and the aims of the study were explained. If the child and parent were keen to participate informed consent was obtained.

8.2.2 Measures

(a) Body anthropometry:

Stature (standing height) was measured standing using a stadiometer (Holtain, Ltd) to the nearest mm. Weight was measured using SECA electronic scales, to the nearest 0.1 kg. Body mass index (BMI) was computed as kg/m^2 . Waist circumference (to the nearest mm) was measured with a flexible non-stretchable tape measure at the level of the narrowest point

(b) Exercise tolerance:

The measure of fitness used in Study three was the 20-MST however this could not be used in a clinical setting due to space limitations. Measurement of exercise tolerance was performed by the Modified Balke Treadmill Protocol. The Modified Blake Treadmill Protocol is performed on a treadmill and is flexible so that it can be adapted to the child's age and fitness level (ACSM, 2000). In this protocol the grade is adjusted while the speed is kept constant. The speeds selected depending on the activity level of the child. The starting speed for those believed to be poorly fit is 3mph at an initial gradient of 6% while that of those believed to be active or athletic are 5 and 5.25 mph with a gradient of 0%. Each stage lasts two minutes and each increment is 2 or 2.5% . The test is maximum and the subjects stopped when they could no longer continue despite encouragement. Maximum oxygen consumption calculated in ml/kg/min was calculated from the following VO_2 if walking (speeds of 1.9 – 3.7mph).

$$\text{VO}_2 = 0.1 (\text{speed}) + 1.8 (\text{speed}) (\text{fractional grade}) + 3.5$$

$$\text{VO}_2 \text{ if running (speeds } > 5\text{mph)}.$$

$$\text{VO}_2 = 0.2 (\text{speed}) + 0.9 (\text{speed}) (\text{fractional grade}) + 3.5$$

(ACSM, 2000).

Results for exercise tolerance in study five were compared to normal values detailed in the Fitnessgram (Freedson *et al.*, 2000) . The Fitnessgram is a test battery for 5-17 year olds and includes four health related fitness variables. Subjects can be classified as fit (i.e. reaching the

minimum criteria) or unfit (failing to reach the minimum criteria). The Fitnessgram programme measures a number of health-related fitness components. Measures of cardiovascular endurance (1-mile-run-walk), body composition (skin-folds and BMI), upper body strength and endurance (pull- ups), abdominal strength and endurance (sit-ups). Exercise tolerance was calculated and presented as a percentage of minimal normal values based on the minimal figure within a normal band based on the data in the Fitnessgram for cardiovascular endurance which is age and gender specific. Normal minimal values for girls aged 10 –17 years are 40 to 35 ml/kg/min. The normal minimal value for boys aged 10-17 years is 42 ml/kg/min.

8.3 Results

Between September 2002 and June 2004 45 children (25 girls and 20 boys) participated in the study. The mean age of the girls and boys was 11.72 ± 2.8 years and 13.1 ± 2.7 years respectively. Table 1 outlines age, body mass index, waist circumferences in the subjects studied.

Table 1: Age, body mass index, waist circumference

	Boys N=20	Girls N=25
Age (mean and SD) in years	13.1 ± 2.7	11.72 ± 2.8
BMI (mean and SD)	30.5 ± 5.0	30.7 ± 6.1
Waist circumference (mean and SD) in cm	99.2 ± 11.4	93.5 ± 6.1

Figure 1. Exercise tolerance as a percentage of normal minimal values

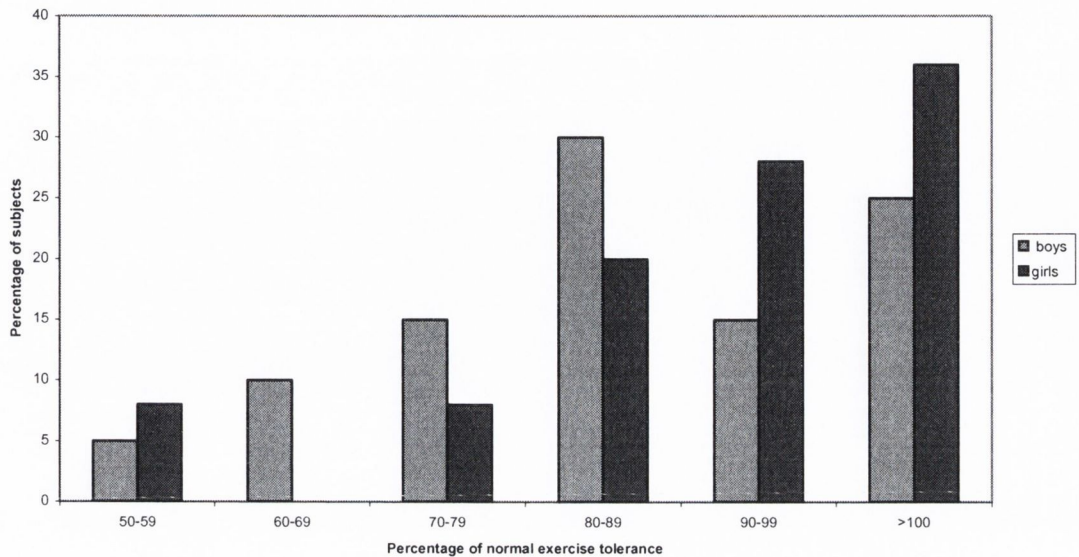


Figure 1: Exercise tolerance as a percentage of normal values for age and gender

Exercise tolerance was calculated and presented as a percentage of minimal normal values (see Figure 8.1) based on the minimal value within a normal band found in the Fitnessgram which is age and gender specific. Normal values for girls aged 10-17 years are 40 to 35 ml/kg/min. Mean and standard deviation for the exercise test value for girls in this study was 33.3 ± 6.0 ml/kg/min. Normal minimal values for boys of 10-17 years are 42. Mean and standard deviation for exercise test for boys in this study was 36.2 ± 6.6 ml/kg/min.

The exercise test was symptom limited and the reason 8 (18%) subjects stopped was due to musculoskeletal pain in the back or lower limbs.

8.4 Discussion

This study of forty five children (25 girls and 20 boys) attending a weight reduction clinic found a high incidence of low exercise tolerance. In terms of BMI and waist circumference the mean figures for both genders (of 30.7 ± 6.1 and 93.5 ± 6.1 cm in girls and 30.5 ± 5.0 and 99.2 ± 11.4 cm in boys) would indicate a high risk for disease based on adult results and the fact that these are already demonstrated in children is of particular concern.

Exercise tolerance was below the minimal recommended in 64% of girls and 75% of boys. Comparison with other data sets must be done with caution due to different populations and methods of measuring exercise tolerance. The exercise tolerance data was also compared to the fitness levels in study three and the values were considerably less than those in children of normal weight. In study three the mean values for fitness in the boys was 53.2 (52.1, 54.3) compared to 36.2 ± 6.6 ml/kg/min in this study and in girls the mean values in study three was 49.5 (48.9, 50.1) compared to 33.3 ± 6 ml/kg/min in the current study. Exercise tolerance was measured on the treadmill and work rate was increased up to a symptom limited maximum. In seven subjects (18%) exercise was terminated due to pain in the knees or feet rather than breathlessness. Research suggests that there is a positive correlation between obesity and musculoskeletal disorders with back pain and knee pain being the most common musculoskeletal complaints (Kortt, and Baldry, 2002; Leboeuf *et al.*, 1999).

In conclusion low levels of exercise tolerance were found in this group of children with obesity. Treatment of children with obesity needs to focus on this risk factors in addition to weight loss.

Exercise Tolerance and Physical Activity Levels in Children Referred to a Weight Reduction Clinic

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Abstract

The aim of this study was to investigate exercise tolerance and physical activity levels in children with exogenous obesity. Measures included BMI, waist circumference, exercise tolerance and self reported physical activity. Exercise tolerance was measured by the Modified Balke Treadmill Protocol and results were compared to normal values. Physical activity levels were assessed by measuring energy expended in regular activities each week over the past year and number of hours spent watching TV/video using an adaptation of the 'Modifiable Activity Questionnaire for Adolescents'. Details on transport to school were also obtained. Forty five children between September 2002 and June 2004 were assessed. This group comprised of 25 girls and 20 boys with mean ages (standard deviation) of 11.9 ± 3.0 years and 13.7 ± 2.5 years respectively. Exercise tolerance as a percentage of normal was below minimal levels in 64% girls and 75% boys. Energy expended in regular activity was less than the minimal recommendation in 80% girls and 65% boys. Seventy six percent of girls and 70% of boys spent 2 hours or more per day watching television and 40% of girls and 70% of boys walked to school. The low levels of activity and exercise tolerance need to be addressed in the management of children with obesity.

Introduction

The prevalence of obesity worldwide has been increasing so rapidly that it is now considered a global epidemic. Recent data suggest that 20% of children in the US are overweight.¹ In England between 1984 and 1994 there was an increase from 5% to 9% and 9% to 13% in obesity levels in boys and girls respectively.² Even in children as young as 4 years of age there has been a significant increase in weight and body mass index (BMI) between 1989 and 1998.³

A low fitness level has been identified as a cardiovascular risk factor in adult males.⁴ The protective effect of physical activity and fitness on cardiovascular risk profile in children needs further study as recently it has been found that fit but obese children had as low levels of inflammatory parameters as lean unfit children indicating that fitness counteracts inflammation associated with obesity.⁵ Fitness has also been found to be inversely correlated to CRP (an inflammatory marker) in boys ($p < 0.01$)⁶ and high levels of physical activity have been found to be associated with favourable lipid profiles in children and adolescents.^{7,8}

The aim of this study was to determine physical activity levels and exercise tolerance in children with exogenous obesity referred to a weight reduction programme in the National Children's Hospital, AMNCH.

Methods

Subjects were children between 6 and 16 years with exogenous obesity and all had the following measurements:

Body Anthropometry

Height was measured to the nearest 0.1 centimetre without shoes using a fixed wall mounted stadiometre (Holtain Ltd). Weight was measured in light indoor clothing using an electronic scale (Seca-alpha). BMI was calculated. Waist circumference was measured in centimetres by a tape measure at the narrowest part between the end of the ribs and the iliac crest.

Physical Activity Levels

Physical activity levels were assessed by measuring energy expended in regular activities each week over the past year, using an adaptation of the 'Modifiable Activity Questionnaire for Adolescents'.⁹ The reproducibility and validity of the original questionnaire has been established and the questionnaire as modified for an Irish population is described in a paper detailing a study assessing physical activity in Dublin children of 7-9 years.¹⁰ A threshold for minimal MET/hr/week was calculated (a child participating in 60 minutes exercise per day for 4 days of the week (most days) at a moderate intensity (i.e. 6 METS) and this resulted in 24 MET/hr/week (based on MET tables and

calculations as previously detailed).^{10,11} Children were also questioned on the number of hours per day spent watching television and mode of transport to school.

Exercise Tolerance

Measurement of exercise tolerance was performed by the Modified Balke Treadmill Protocol. The test is maximum and the subjects stopped when they could no longer continue despite encouragement. Calculations for maximum oxygen consumption were calculated.¹² Results for exercise tolerance were compared to normal values detailed in the Fitnessgram.¹³

Results

Between September 2002 and June 2004 45 children (25 girls and 20 boys) participated in the study. The mean age of the girls and boys was 11.72 ± 2.8 years and 13.1 ± 2.7 years respectively. Table 1 outlines age, body mass index, waist circumferences, mode of transport to school and hours spent TV/video watching per day.

Exercise tolerance and physical activity levels as percentage of normal predicted values are presented in Figures 1 and 2.

Exercise tolerance was calculated and presented as a percentage of minimal normal values based on the minimal figure within a normal band based on the data in the Fitnessgram which is age and gender specific. Normal minimal values for girls aged 10-17 years are 40 to 35 ml/kg/min. Mean and standard deviation for the exercise test value for girls in this study was 33.3 ± 6.0 ml/kg/min. Normal minimal values for boys of 10-17 years are 42. Mean and standard deviation for exercise test for boys in this study was 36.2 ± 6.6 ml/kg/min. The exercise test was symptom limited and the reason 8 (18%) subjects stopped was due to musculoskeletal pain in the back or lower limbs. Energy expenditure in regular activity was calculated and presented as a percentage of the minimal recommended level of 24 MET/hr/week (see methodology).

Discussion

This study of forty five children (25 girls and 20 boys) attending a weight reduction clinic found a high incidence of low exercise tolerance and decreased physical activity levels. With increasing incidence of paediatric obesity the impact of associated cardiovascular risk factors will place an enormous burden on already stretched health services. In terms of BMI and waist circumference the mean figures for both genders (of 30.7 ± 6.1 and 93.5 ± 6.1 cm in girls and 30.5 ± 5.0 and 99.2 ± 11.4 cm in boys) would indicate a high risk for disease based on adult results and the fact that these are already demonstrated in children is of particular concern.

Table 1: Age, body mass index, waist circumference, numbers walking to schools and hours spent watching TV/video per day

	Boys N=20	Girls N=25
Age (mean and SD) in years	13.1 ± 2.7	11.72 ± 2.8
BMI (mean and SD)	30.5 ± 5.0	30.7 ± 6.1
Waist circumference (mean and SD) in cm	99.2 ± 11.4	93.5 ± 6.1
Numbers walking to school	14	10
Number watching TV/video ≥ 2 or more hours/ day	14	19

Figure 1: Exercise tolerance as a percentage of normal minimal values

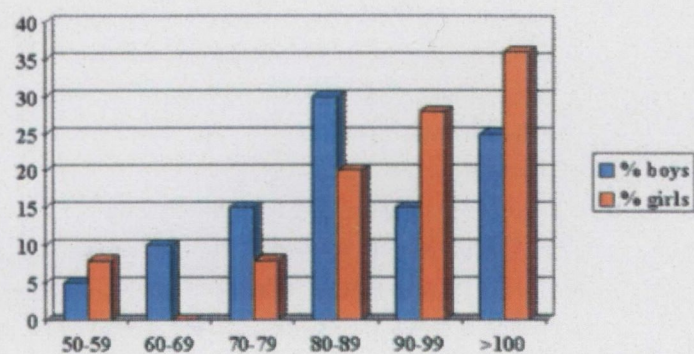
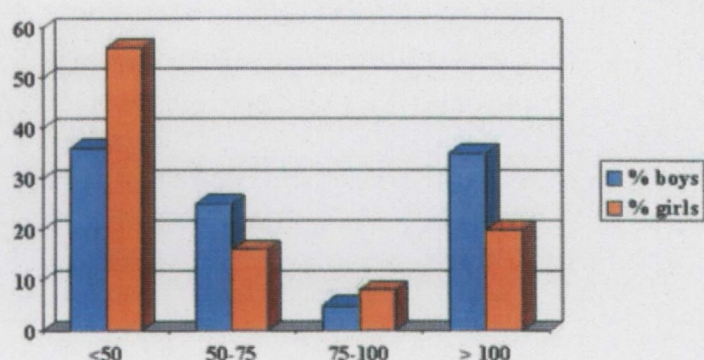


Figure 2: Physical activity as a percentage of normal minimal values



As these children presented with low activity levels and exercise tolerance the potential for increasing activity and fitness and thus decreasing the overall risk profile is evident. In addition the impact of increasing activity levels and fitness on blood pressure and lipid levels requires further study.

Physical activity levels as measured by energy expenditure in were regular activity below the minimal level in 80% of girls and 65% of boys. Measuring physical activity by self report can be questioned in terms of reliability and validity as children engage in activity that is sporadic in time and in intensity and therefore may find the task of recalling activities difficult.

Exercise tolerance was below the minimal recommended in 64% of girls and 75% of boys. Exercise tolerance was measured on the treadmill and work rate was increased up to a symptom limited symptom limited maximum. In seven subjects (18%) exercise was terminated due to pain in the knees or feet rather than breathlessness. Research suggests that there is a positive correlation between obesity and musculoskeletal disorders¹⁴ with back pain and knee pain being the most common musculoskeletal complaints.^{15,16} The current management of the children in this study includes individualised exercise prescription and the results of such an intervention are awaited.

In conclusion low levels of exercise tolerance and physical activity were found in this group of children with obesity. Treatment of children with obesity needs to focus on these risk factors in addition to weight loss.

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Appendix 7: Publication resulting from Study 1

Physical activity in Dublin children aged 7-9 years

J Hussey, J Gormley, C Bell

Abstract

Objectives—To investigate the amount of regular activity and time spent in sedentary occupations in children aged 7-9 years. Sex differences in levels of activity and time and facilities for physical education at school were also examined.

Methods—A 10% sample of Dublin National Schools were selected. Parents of children in second class were surveyed. The questionnaire used was a modification of the Modifiable Activity Questionnaire for Adolescents. Teachers of second class were questioned about the time and facilities for physical education in schools.

Results—Some 39% of children were participating in hard exercise for at least 20 minutes three or more times a week, with fewer girls (28%) than boys (53%) contributing to this result. A further 57% of children were engaging in at least 20 minutes of light exercise three or more times a week, with no sex differences. Estimated energy expenditure in regular activity was higher in boys than girls. Most (78%) of the children were spending one to three hours a day sedentary in front of a screen. **Conclusions**—This study provides comprehensive data on physical activity levels in Dublin schoolchildren aged 7-9 years. The amount of inactivity is of concern. Even at this young age, boys are reported to participate in more physical activity than girls.

(Br J Sports Med 2001;35:268-273)

Keywords: physical activity; exercise; children

Regular physical activity by adults is associated with a decreased risk of coronary artery disease.¹ Inactivity in childhood can influence activity patterns in adulthood² and may increase susceptibility to obesity and cardiovascular disorders.^{3,4} The American College of Sports Medicine⁵ and The National Institute of Health Consensus⁶ advocate an accumulation of at least 30 minutes of moderate intensity physical activity on most days of the week.

A 1989 study of fitness and activity levels in 10-13 year old Irish children found that one third of the sample exercised four or more times a week.⁷ Only 23% walked or cycled to school. A study in 1998 examining 9-17 year old Irish children found that 53% exercised four or more times a week.⁸ Boys exercised more than girls, and for both sexes exercise participation decreased with age.

The amount of time spent by children watching television may influence their levels of physical activity. In 1989, Irish children were found to spend a mean of 2.95 hours watching

television.⁷ In the United States in 1998, Andersen *et al*⁹ found that 67% of children aged 8-16 years watched at least two hours of television a day, with 26% watching more than four hours. Children who watched more than four hours a day had more body fat ($p < 0.001$) than those who watched less than two hours a day.

Measuring habitual physical activity in children poses many challenges. Methods such as measurement of energy expenditure by determination of oxygen consumption, although accurate, involve equipment (facemask/mouthpiece) that may interfere with normal activities, and are limited in large studies because of time and expense. The doubly labelled water technique does not restrict activity, but one disadvantage is its high cost.¹⁰ Recording of heart rate and movement counters are practical alternatives in field settings, but, for very large scale studies in which simple methods are required, questionnaires are commonly used. Younger children have limited information about their activity patterns, and parents or teachers may be questioned about a child's activity.

In contrast with the data on exercise patterns in older children and teenagers, there are few published reports on physical activity in Irish children under 9 years of age. This, coupled with the concern that general physical activity levels are less than they were 20 years ago, led to the initiation of this study, which aimed to determine physical activity levels in 7-9 year old children in Dublin National Schools.

The objectives were to determine:

- the amount of overall activity (duration, frequency, and number of activities);
- the amount of time in sedentary occupations;
- any sex differences in levels of physical activity;
- the time and facilities for physical education (PE) in schools.

Methods

A list of National primary schools in Dublin was obtained from the Department of Education and Science. The list consisted of 396 schools suitable for inclusion (excluding schools for children with special needs). The schools were then coded by deprivation index into five areas where 1 is the highest (socioeconomically) and 5 is the lowest (SAHRU Technical report).¹¹ The Republic of Ireland is divided into 3440 District Electoral Divisions (smallest administrative areas for population statistics), and the indicators used in defining the five areas of deprivation index areas are: unemployment, low social class, no car, rented accommodation, and overcrowding. Schools

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Table 1 Return rates from schools, subject numbers, and mean METs/hour/week in areas 1–5

	1	2	3	4	5
Number of schools surveyed	16	8	2	8	3
Mean (range) return rate (%)	53 (14–94)	41 (16–91)	42 (40–45)	48 (23–93)	38 (27–60)
Number of subjects in study	473	157	45	82	29
Mean METs/hour/week	36	40	40	42	70

are listed according to postal code. To ensure geographical spread, every 10th school was selected from each of the five (deprivation index) areas.

The principal of each selected school was contacted and the aim of the study was explained. Then a copy of the questionnaire and a letter of explanation were sent. If a school declined to participate in the study, the next school on the list within the same area was selected (for areas 1, 2 and 4, three schools declined, for areas 3 and 5, two schools declined). After consent from the school, questionnaires and consent forms for parents were delivered to the school. As it was the parents who were to fill in the questionnaire, they also received a letter of explanation.

The questionnaire was a modification of the Modifiable Activity Questionnaire for Adolescents.¹² The reproducibility and validity of the original questionnaire was established by Aaron *et al.*¹² As the children in this study were much younger than adolescents, it was thought that parents would provide more reliable and accurate information about time spent in physical activity. In the original questionnaire, the first question sought information on the number of times in the preceding two weeks that the child had participated in at least 20 minutes of hard exercise, hard exercise being defined as exercise that resulted in heavy breathing and a fast heart beat. Information on the number of times in the preceding two weeks that the child had participated in at least 20 minutes of light exercise was sought in the second question. Light exercise was defined as exercise that did not result in heavy breathing or a fast heart beat. The third and fourth questions dealt with the number of hours a day spent watching television, videos, or playing computer games and the number of competitive activities in which the child participated.

The final question sought to estimate the energy expended in regular physical activity each week. The parent indicated in which activities the child participated regularly over the preceding year. For each activity, the number of months over the year, the average number of days a week, and the average minutes a day that it was performed were ascertained. The above information was used to calculate the hours a week spent at each activity as follows:

$$\text{hours a week} = (M \times (4.3 \text{ weeks/month}) \times D \times N) / ((60 \text{ min/h})(52 \text{ weeks/year}))$$

where M is the number of months, D is the number of days a week, and N is the number of minutes a day.

Energy expended in regular activities each week—that is, metabolic equivalents (METs)/hour/week—was determined by multiplying the hours a week spent at each activity by the

metabolic cost of each activity in METs (tables in Montoye *et al.*¹³). An arbitrary threshold for minimal METs/hour/week was calculated on the basis of a child exercising for 30 minutes a day for four days of the week (most days) at a moderate intensity (7 METs):

$$\begin{aligned} \text{minimal METs/hour/week} &= ((12 \times 4.3 \times 4 \times 30) / (60 \times 52)) \times 7 \text{ METs} \\ &= 1.98 \times 7 \text{ METs} \\ &= 13.9 \text{ or } 14 \text{ METs/hour/week.} \end{aligned}$$

The modifications to the original questionnaire included the addition of a question on transport to school, and, as these children were under 9 years of age, the question on involvement in competitive activities was removed. Under the past year activities, sports played in Ireland such as Gaelic football, hurling, and rugby were added.

A questionnaire was sent to teachers of the children in second class in the participating schools. The questionnaire for teachers contained questions on the frequency, duration, and location of PE classes during school hours.

DATA ANALYSIS

Data were coded and entered into Excel (Microsoft). Descriptive analysis was performed. χ^2 tests were used for comparison of variables between sexes. *t* tests (unpaired) were used to compare differences between sexes and METs/hour/week and to compare children from different areas and METs/hour/week.

Results

Thirty seven schools participated in the study. Average return rates from each school ranged from 38% in area 5 to 53% in area 1 (table 1). However, the number of schools in each area (as coded by the deprivation index) was very different—for example, there were 16 schools in area 1 compared with two schools in area 3. In total, 786 questionnaires were analysed. Of the 786 subjects, 352 were boys and 434 were girls. Eighty six (11%) had a medical condition that could interfere with physical activity (74 had asthma).

Some 39% of children participated in at least 20 minutes of hard exercise three or more times a week; significantly more boys (53%) than girls (28%) contributed to this result ($p < 0.001$) (fig 1A). There were no significant sex differences in the participation in light exercise, with 57% of children exercising lightly for at least 20 minutes three or more times a week (fig 1B).

An examination of the mode of transport to school showed that 40% of children (44% boys, 37% girls) walked to school and 33% (31% boys, 35% girls) were brought to school by car. For 22% (21% boys, 29% girls), a combination of walking and being driven to school was reported, and 5% of children travelled by

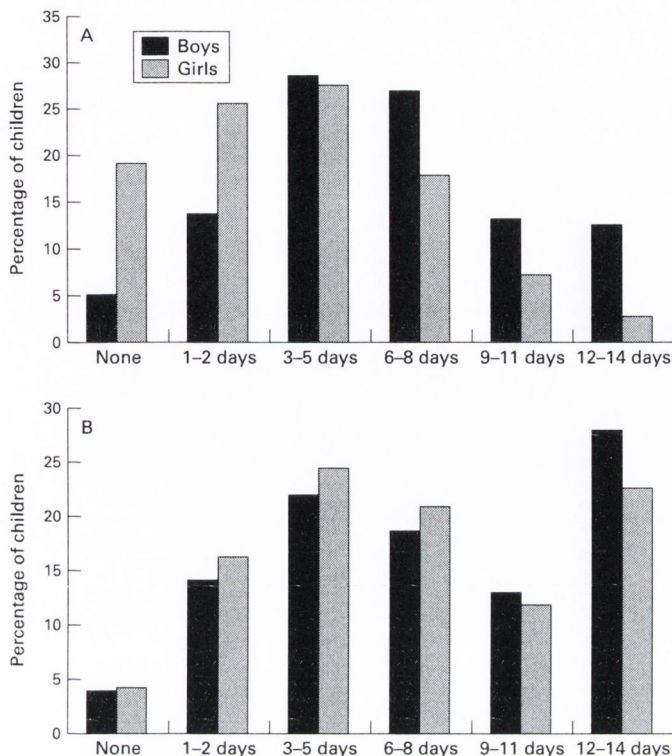


Figure 1 (A) Number of days in the past 14 on which the child spent at least 20 minutes in hard exercise. (B) Number of days in the last 14 on which the child participated in at least 20 minutes of light exercise.

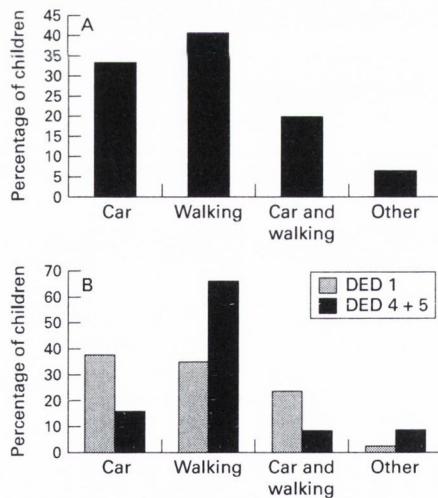


Figure 2 (A) Mode of transport to school. (B) Comparison of mode of transport to school between lowest and highest deprivation areas (DED, District Electoral Division).

bus (fig 2A). Figure 2B shows that 35% of children in area 1 walked to school compared with 66% in areas 4 and 5.

Table 2 shows that 60% of children were spending up to three hours a day in front of a screen, and 18% were spending more than three hours a day. No sex differences were seen. No differences in the number of hours spent watching television/videos or playing computer games were seen when area 1 was compared

Table 2 Time spent watching television/videos or playing computer games

Time (hours a day)	Boys (%)	Girls (%)
None	1	2
1 hour or less	19	22
2-3 hours	62	58
4-5 hours	9	13
6 hours or more	8	5

Table 3 Time spent watching television/videos or playing computer games: comparison between area 1 and areas 4 and 5

Time (hours a day)	Area 1	Areas 4 and 5
None	1.5	2.6
1 hour or less	24	11.1
2-3 hours	59.2	60.7
4-5 hours	9.9	15.4
6 or more	5.3	9.4

Values are percentage of children.

with areas 4 and 5 (table 3). As 14 METs/hour/week was used as a minimal level of regular activity participation, the number of subjects falling beneath this activity threshold was calculated. Some 14% of boys and 24% of girls were reported to engage in less than the minimal recommendation. Overall, boys were expending significantly more energy in regular activities than girls (46 v 33 METs/hour/week) ($p < 0.001$). The hours spent watching television/video or playing computer games was compared with energy expended in regular activities (fig 3). Subjects were divided into two groups according to whether they spent more or less than three hours a day sitting in front of a screen, and the leisure time energy expenditures of the two groups were compared for the two sexes; no differences were seen.

Although there were considerable differences in the number of subjects between the five areas, overall activity in areas 4 and 5, as measured by METs/hour/week, was compared with area 1. Children in areas 4 and 5 expended significantly more energy in regular activity than children in area 1 (45.9 v 35.8 METs/hour/week; $p < 0.005$).

TEACHERS' RESPONSES

Sixty eight questionnaires were sent to teachers, and 49 were returned, making a response rate of 72%. Teachers reported that they had one or two PE classes a week (a mean of 1.5). The duration of PE classes was 10-60 minutes. All but one teacher reported that it was obligatory to participate in the class. The location of the classes varied, often depending on the

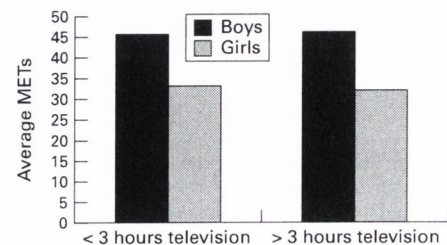


Figure 3 Average METs for boys and girls watching less than three hours of television and those watching more than three hours of television.

weather, but all had a gym or hall for PE sessions. The mean length of time per session that children were reported to spend in vigorous activity was 15 minutes (range 5–45). Where appropriate, boys and girls did the same activities.

Discussion

The topic of physical activity in children has received much attention in recent years. This study differs from many others in that it examines physical activity levels in children from differing socioeconomic groups.

RETURN RATES

The return rates of the questionnaires ranged from a mean of 38% in area 5 to a mean of 53% in area 1 but within these the ranges were large. As the number of schools in each area differed and an overall 10% sample was selected, the number of subjects ranged from 473 in area 1 to 29 in area 5. With such small numbers in some areas, it was difficult to compare data acquired with respect to differences in socioeconomic status. Because of the very low response rate in area 5, it is possible that the results from this area may not be totally representative. Principals in some schools commented that literacy or language problems could have influenced the response rate. It was not possible to chase up non-responders because it was the headmaster/teachers who were responsible for the circulation and collection of questionnaires.

PARTICIPATION IN HARD EXERCISE

It was found that 39% of children were participating in hard exercise for at least 20 minutes three or more times a week. This figure is low compared with the figure of 53% reported for an older age group (9–17 years) who exercised four or more times a week.⁸ However, the fact that a premise of at least 20 minutes was stipulated may be a reason for this lower result. Prolonged exercise may not be the natural choice of younger children for whom activity may be typically intermittent.¹⁴ Fewer girls were participating in hard exercise, and this sex difference was also seen in a recent Irish study in which 45% of girls compared with 62% of boys reported exercising four or more times a week.⁸ Sex differences in the amount of vigorous physical activity performed have been reported by others, with girls exercising less than boys of a similar age.^{14–16}

TYPE OF ACTIVITIES

Energy expenditure in regular physical activities was higher in boys, implying that boys participate in more vigorous activities for longer and/or more frequently than girls. Common activities preferred by boys, such as rugby, hurling, and soccer, require on average higher energy expenditure than some more female orientated activities of children of this age such as ballet. It is worrying that 24% of girls and 14% of boys are exercising less than the minimal recommendation. This study, however, only addressed regular physical activity and not the intermittent sporadic activity that is naturally seen in children

of this age if given the opportunity. There was a difference in energy expended on regular activity between children in areas 4 and 5 combined compared with those in area 1, but these results may need to be interpreted with some caution because of the difference in numbers and low response rate in area 5.

AMOUNT OF PE DURING SCHOOL HOURS

All schools had either one or two periods of PE a week, with a mean duration of 20–30 minutes. Teachers reported that the locations for PE were appropriate, but some teachers stated that more time should be devoted to PE, as they were concerned about the general levels of physical activity in children.

PARTICIPATION IN LIGHT EXERCISE

Overall, 57% of children were reported to engage in 20 minutes of light exercise at least three times a week, and there were no significant differences between the sexes. Other studies have reported minimal or no difference in moderate activity between boys and girls.^{14 15} Of concern is the lack of even moderate activity in 43% of the sample. Activities such as cycling and walking are important lifestyle activities that can help to prevent many diseases in adulthood. Formation of these lifestyle habits in childhood may influence activity patterns in adulthood.² Of interest was the difference in the proportion of children in area 1 and areas 4 and 5 who walked to school—that is, comparing those of higher socioeconomic status with lower. Overall, 33% of children were driven to school by car and 5% went by bus. Some 40% walked, and 20% walked part of the way. These figures are in contrast with a previous study in 1990, in which 77% of primary schoolchildren were driven to school.⁷ It is not clear in the latter study whether some children were from rural areas that were too distant from school for walking.

TIME SPENT IN SEDENTARY OCCUPATIONS

Watson¹⁷ reported that Irish children spend a mean of just under three hours a day watching television, and in the United States it has been reported that 67% of children watch television for at least two hours a day.⁹ The figure in this study of 77% spending at least two or three hours a day in front of a screen is higher, but includes the playing of computer games as well as watching television. This amount of time spent sedentary each day is of concern because it can be correlated to the amount of body fat.⁹ No differences were seen in energy expended in regular activity for those spending more or less than three hours a day in front of a screen, but the time spent sitting may be at the expense of unorganised spontaneous activity, which was not assessed in this study. Regular activities such as swimming, ballet, and rugby tend to be planned in advance, whereas television is watched at times when the child is free from school or organised activities.

LIMITATIONS OF THE STUDY

One limitation of the study is that it uses subjective evaluation of the frequency and duration of activity by the parents, which could lead to an overestimation. We acknowledge that, whereas the questionnaire used was validated in teenagers, it was completed in this study by parents because of the relatively young age of the children studied. Return rates from areas of lower socioeconomic status were low compared with those from areas of higher socioeconomic status, which may have led to bias. Another limitation is that the questionnaire investigated regular physical activity and did not take into account non-organised play in the school yard, garden, park, etc. When children are playing outside, parents may be unaware of the amount of activity engaged in. It has also been documented that children of this age may not often participate in vigorous activity of 70% of maximum heart rate for 20 minutes or more in one session. Armstrong *et al*¹⁸ found that five minutes of intense activity, as measured by continuous heart rate monitoring in sixth year (primary) children, was common and that few children spent periods of 20 minutes or longer with heart rates above the recommended threshold (140 beats/min). Monitoring of heart rate would not have been feasible for a study involving nearly 800 subjects, and activities suggested under "hard exercise", such as basketball/football, were activities in which children of this age participated. It may be worth investigating heart rates achieved during a session of football/basketball in this age group, as Armstrong *et al*¹⁸ did not relate heart rate findings to specific activities.

CONCLUSION

This study presents results on physical activity levels in a large sample of Dublin schoolchildren in the 7–9 year age group. Although direct comparisons with other studies are difficult because of the different methods used, many of the findings of this study are similar to those in many other published reports. Despite the limitation of the method of measuring regular activity, our data support findings of previous studies that boys participate in more physical

activity than girls even at this young age.^{8,18} A worrying number (14% boys and 24% girls) are not performing the volume of physical activity necessary to benefit the cardiovascular system. However, the limitation of not assessing non-organised intermittent activity needs to be addressed, as this type of activity is natural in young children. Furthermore the influence of overall activity and fitness levels needs to be investigated.

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Take home message

In a group of 7–9 year old Irish children, boys were found to be more active than girls, nearly a quarter of whom are performing less than the volume of activity recommended for cardiovascular benefits. Of particular concern is the time spent in sedentary occupations and the lack of participation in even light to moderate activity such as walking and cycling.

Commentary

It is becoming increasingly clear just how inactive children are nowadays. This paper confirms in Irish children what previous studies have indicated in Ireland, elsewhere in Europe, in North America and, to a lesser extent in South-East Asia, and the antipodes. It shows the impact television and computer games are having everywhere, and, by differentiating periods of low levels of activity interspersed with spans of more vigorous activity, it draws special attention to the care we need to have in describing children's activity. Social factors are important in determining disease, so it should come as no surprise to find it influencing childhood behaviour too. The authors have performed a service in opening this aspect, but they have found it difficult to obtain quite what may be required if policy is to be developed to rectify it. Do not seek here the solutions to this problem affecting so many parts of the world, but do ensure that the opinion leaders know that, so far, no nation seems immune from this creeping physical inactivity.

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Commentary

The case for physical activity and health in children is widely accepted and promoted by health authorities,¹ but is set against a background of rapidly increasing levels of obesity² for which increasingly sedentary lifestyles are largely responsible.³

Characterising and measuring children's activity has proved to be far from easy, as at least five dimensions of activity can impact on different aspects of health.⁴ This study highlights both the worrying trend towards inactivity in children, and the problems of reliably recording overall activity in this young age group by user friendly questionnaire. Accelerometers show promise in measuring activity patterns in children, but have not yet been fully validated, and are currently too expensive to be widely used as a large scale research tool. However, as safety concerns place more restrictions on children's leisure activities, and they are wooed by ever increasing options for sitting in front of various types of screen for entertainment, accurate measurement of activity patterns is essential to find out which children are at risk and why, and to enable effective interventions in making them more active.

DAVID WATKINS

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Appendix 8: Publication resulting from Study 3

ORIGINAL ARTICLE

Relationship between the intensity of physical activity, inactivity, cardiorespiratory fitness and body composition in 7–10-year-old Dublin children

J Hussey, C Bell, K Bennett, J O'Dwyer, J Gormley

Br J Sports Med 2007;41:311–316. doi: 10.1136/bjsm.2006.032045

Objective: To investigate the relationships between the time spent in specific intensities of activity and inactivity, cardiorespiratory fitness and body composition in children.

Methods: A cross-sectional study was conducted in a random sample of schools. Height, weight and waist circumference were measured in 224 children aged 7–10 years. Cardiorespiratory fitness was estimated by the 20 m multistage running test, and physical activity was measured over 4 days by the RT3 (a triaxial accelerometer). Time each day spent in moderate and vigorous intensities of activity was calculated.

Results: Twelve schools agreed to participate in the study. Body composition and fitness data were obtained for 224 children and activity data for 152 children. Boys were found to take part in about twice as much vigorous and hard activity as girls (mean (95% confidence interval) 64.3 (53.2 to 75.4) min in boys compared with 37 (33.1 to 40.9) min in girls; $p<0.001$). In boys there was significant difference between those defined as normal, overweight and obese in the time spent in vigorous activity ($p<0.05$), but no such difference was found in girls. A significant negative correlation between waist circumference and time spent in vigorous activity ($r=-0.31$, $p<0.05$) was found in boys but not in girls. Time spent sedentary was positively correlated with waist circumference in boys ($r=0.33$, $p<0.01$) but not in girls. In both boys and girls there were significant negative correlations between fitness and both body mass index ($r=-0.274$, $p<0.001$) and waist circumference (boys: $r=-0.503$, $p<0.01$; girls: $r=-0.286$, $p<0.01$).

Conclusion: In boys, body composition was inversely related to fitness and to vigorous activity and was positively related to inactivity. In girls, body composition was related to fitness but not to specific components of physical activity.

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Increasing evidence suggests that low levels of physical activity in children and adolescents are related to increased levels of cardiovascular risk.^{1–2} A recent investigation from the European Youth Heart Study group found that the odds ratio for clustered risk was 2.03–3.29 in children from the least active quintiles of physical activity compared with the most active.³

Obesity is a cardiovascular risk factor that is causing increased concern, especially in children. It would appear plausible to assume that higher levels and intensities of physical activity in children result in a more favourable body composition. Studies investigating this relationship have demonstrated conflicting results, with some finding no association,^{4–5} whereas others have found that higher activity levels are correlated with lower fat mass.^{6–10} A meta-analysis by Rowlands *et al* showed that there is a small to moderate relationship between body fat and activity in children.¹¹ There is further uncertainty when one examines gender differences as some investigators have found a relationship between levels of physical activity and body composition in boys but not in girls.^{12–14}

Studies examining the relationship between intensity of activity and body composition have also found varying results. Abbott and Davies found that times spent in vigorous and hard activity (as defined by accelerometer counts per minute) correlated significantly with percentage body fat but not with body mass index (BMI) in 5–10.5-year-olds.¹⁵ Moderate intensity activity, however, was not found to correlate with measures of body composition. In preschool children it has been found that the amount of moderate to vigorous activity is significantly greater in non-overweight boys than in overweight

boys, but no such relationship was seen in girls.¹³ The relationship between time spent sedentary and body fat was investigated in a one year longitudinal study and an increase in inactivity was found to be associated with an increase in BMI in adolescent girls.¹⁶

A definitive understanding of the relationship between activity levels and body composition in children may not be possible owing to methodological differences in the above studies. First, various techniques have been used to determine body composition—for example, BMI, waist circumference and skinfolds. Second, there is variation in the methods used to measure physical activity, with many studies using subjective methods.^{1–7 8 12 16} In studies using more objective methods (for example, accelerometers) there has been limited examination of the influence of the various intensities of physical activity, including inactivity, on body composition.^{9 13}

To clarify the relationship between body composition and activity our study investigated the relationships between body composition, intensity of physical activity and inactivity, and aerobic fitness. The specific objectives of this study were:

- To determine the relationship between moderate, vigorous and hard activity and body composition in children aged 7–10 years.
- To determine the relationship between time spent sedentary and body composition in children aged 7–10 years.
- To determine the relationship between cardiorespiratory fitness levels and body composition in this cohort.

Abbreviations: ANOVA, analysis of variance; BMI, body mass index

Table 1 Mean and 95% confidence intervals of height, body mass index, waist circumference, $\text{VO}_{2\text{max}}$ (ml/kg/min)

Age (years)	Height (cm)	BMI	BMI (z score)	Waist (cm)	$\text{VO}_{2\text{max}}$ (ml/kg/min)
Boys					
7–8 (n=37)	132.9 (131.1 to 134.7)	16.2 (15.3 to 17.1)	−0.013 (−0.48 to 0.46)	61 (58.7 to 63.3)	51.7 (50.2 to 53.2)
8.1–9 (n=37)	135.2 (133.9 to 136.5)	16.8 (16.0 to 17.6)	0.307 (−0.07 to 0.69)	62 (60.1 to 63.9)	55.0 (53.6 to 56.5)
9.1–10 (n=10)	139.3 (135.1 to 143.5)	19.4 (17.8 to 21.5)	1.175 (0.39 to 2.00)	70 (62.5 to 77.4)	51.7 (47.9 to 55.5)
Total (n=84)	134.7 (133.5 to 135.9)	16.9 (16.3 to 17.5)	0.269 (−0.02 to 0.56)	62 (60.3 to 63.7)	64.3 (53.2 to 75.4)
Girls					
7–8 (n=49)	131.6 (130.3 to 132.9)	16.6 (13.0 to 20.2)	0.133 (−0.22 to 0.48)	62 (60.0 to 64.0)	50.5 (49.5 to 51.5)
8.1–9 (n=81)	133.3 (132.2 to 134.4)	16.6 (16.1 to 17.1)	0.047 (−0.18 to 0.28)	62 (60.5 to 63.5)	48.9 (48.2 to 49.6)
9.1–10 (n=10)	136.2 (130.6 to 141.8)	17.8 (15.8 to 19.8)	0.346 (−0.77 to 1.46)	66 (59.8 to 72.2)	49.8 (47.0 to 52.6)
Total (n=140)	132.9 (132.0 to 133.8)	16.7 (16.3 to 17.1)	0.10 (−0.09 to 0.29)	62 (60.8 to 63.2)	49.5 (48.9 to 50.1)
Significance	p=0.023	p=0.59	p=0.31	p=0.78	p<0.001

METHODS

Subjects

Subjects in the study comprised 224 children aged 7–10 years from national primary schools in Dublin.

Children with conditions that might have led to limitations in physical activity and mobility were excluded. Ethical approval for the study was obtained from the joint research ethics committee of St James’s Hospital/Adelaide and Meath incorporating the National Children’s Hospital.

Measures

Body composition

All anthropometric measures were carried out by the same investigator. Height was measured by a portable stadiometer (SECA, Vogel and Halke, Germany) to the nearest millimetre. Weight was measured, using SECA electronic scales, to the nearest 0.1 kg. Both were measured with the child in light clothing (school tracksuit) without shoes. BMI was computed as kg/m^2 . Overweight and obesity were defined using the international cut-off points.¹⁷ The BMI was also standardised to the British reference population and converted to z scores.¹⁸ Waist circumference (to the nearest millimetre) was measured with a tape measure at the level of the narrowest point between the lower costal border and the iliac crest, and measures obtained were compared with centiles in British children.¹⁹ Waist circumference is a measure of central fat, but the BMI was required in order to assign children to categories of normal weight, overweight and obese.

Cardiorespiratory fitness

The 20 m multistage running test²⁰ was used to measure cardiorespiratory fitness. This test has been found to be a valid

predictor of $\text{VO}_{2\text{max}}$ in children and adolescents.^{21–22} It was explained in full before the start and all testing was done in dry weather conditions in school yards with concrete surfaces.

Physical activity

The RT3 accelerometer (Stayhealthy Inc, Monrovia, California, USA) was used for the objective measurement of physical activity. The RT3 can assess activity in three planes, and records intensity, frequency and duration of activity. Physical activity can be expressed as total energy expenditure or as minutes spent each day in different intensities (the output is expressed as mean counts per minute). Activity was quantified as overall energy expenditure in physical activity and minutes in light (VM (Vector Magnitude): 100–970), moderate (VM: 971–2333), vigorous (2334–3500)⁹ and hard or vigorous activity (>3500).²³ These intensities mean that walking at 3 km/h would be classified as moderate, walking at 6 km/h would be vigorous and running at 9 km/h would be hard activity. Data were averaged over the four days and expressed as mean minutes spent daily. The days of the week varied and 38 children had both two days of weekend and week days monitored, 26 had three week days and one week end day and the rest had all week days measured. The validity of the RT3 in the measurement of physical activity in boys of this age has been established²³ and the TriTrac (predecessor to the RT3) has been validated in both genders of this age.²⁴

Sampling and design of the study

To determine a correlation of 0.2 or greater between activity levels and BMI it was calculated that 195 children would be required for the study to have 80% power of detecting a correlation and a two tailed level of significance of 5%.

Table 2 Mean and 95% confidence intervals of minutes per day spent in inactivity, moderate activity, vigorous activity, hard activity and hard/vigorous activity as estimated by triaxial accelerometry

Age (years)	Sedentary	Moderate	Vigorous	Hard	Vigorous/hard
Boys					
7–8 (n=23)	927.6 (897.1 to 958.0)	115 (100.7 to 129.3)	40.6 (33.2 to 48.0)	23.4 (16.1 to 30.7)	56 (43.8 to 68.2)
8–9 (n=23)	917.5 (880.8 to 954.2)	117 (104.7 to 129.3)	33.8 (25.1 to 42.5)	22.3 (13.7 to 30.9)	56 (43.8 to 68.2)
9–10 (n=6)	1028.5 (951.4 to 1105.6)	70 (52.4 to 87.6)	21.0 (13.4 to 28.6)	16.2 (12.3 to 30.1)	66.3 (15.1 to 117.5)
Total (n=52)	935.1 (910.8 to 959.4)	110.5 (101.0 to 120.0)	37.6 (32.3 to 42.9)	22.1 (16.9 to 27.3)	64.3 (53.2 to 75.4)
Girls					
7–8 (n=36)	945.6 (909.3 to 981.9)	95 (83.9 to 106.1)	22.6 (19.0 to 26.2)	9.4 (6.6 to 12.1)	30 (24.6 to 35.4)
8–9 (n=59)	970.5 (950.9 to 990.2)	98 (92.0 to 104.0)	26.1 (23.4 to 28.8)	13.9 (10.5 to 17.3)	41 (35.9 to 46.1)
9–10 (n=5)	1015.0 (965.4 to 1064.5)	82 (62.7 to 101.3)	16.0 (9.95 to 22.0)	6.7 (2.7 to 10.7)	22.2 (14.2 to 30.2)
Total (n=100)	963.8 (945.8 to 981.8)	96.1 (90.6 to 101.6)	24.5 (22.3 to 26.6)	12.1 (9.8 to 14.4)	37 (33.1 to 40.9)
Significance	p=0.068	p=0.007	p<0.001	p=0.068	p<0.001

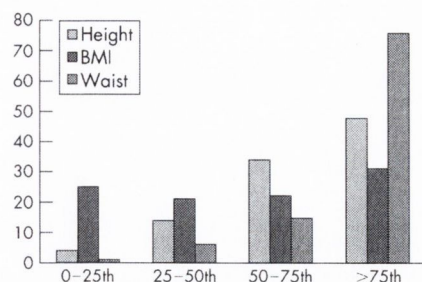


Figure 1 Centiles of height, BMI, waist circumference with respect to the British 1990 growth references (n=224).

Stratified (geographically) random sampling was used in this cross-sectional study. Schools were identified from the Department of Education and Science website (<http://www.education.ie>, accessed 31 January 2007) and were randomly selected from each of the four Dublin borough areas (Dublin Borough, Dublin Fingal, Dublin South, Dun Laoghaire-Rathdown) on a proportional basis. Principals of the schools were contacted, the aims of the study were explained and the call was followed up with a letter to be approved by the school boards, where necessary. Once a school had agreed to participate in the study, letters to parents and consent forms were distributed. A convenient morning was arranged with each school for testing and children were asked to wear their school tracksuit/gym clothing for the day of testing.

The procedure required a number of visits to each school. At the first visit height, weight, waist circumference, and cardiorespiratory fitness were measured. The RT3 was given to six children for four days with instructions on its use. Four days of activity has been found to be a sufficient length of time to determine habitual activity levels in children.²⁵ On collection the RT3s were downloaded, re-initialised and given to the next group of six children.

Statistical analysis

Activity was described by the minutes spent in various intensities of activity as stated above (see "Measures"). Descriptive analyses are presented for continuous data as means and confidence intervals, and for categorical data as percentages. BMI was standardised for age and gender, and also categorised into three divisions (body composition) based on the international cut-off points for BMI for overweight and obesity in children. Although there are Irish growth references,²⁶ these do not include waist circumference, so for consistency the British standards were used. Comparison of height, weight, BMI, standardised BMI, activity and VO_2 levels

between the genders was made using an independent *t* test, and between the body composition variables using analysis of variance (ANOVA). Pearson correlations were calculated between standardised BMI and activity and fitness levels and repeated for boys and girls separately. Multiple regression analysis was performed for various dependent variables (see table 5) and in all cases the model included age, gender, BMI *z* score and waist circumference adjustment. All variables other than minutes spent in vigorous activity (which were subsequently log transformed for analysis) were normally distributed. Significance was assumed at $p < 0.05$ and all analyses were performed using SPSS version 12 (SPSS Inc).

RESULTS

Twenty eight schools were contacted, 12 replied positively and were scheduled into the study. The numbers in each area were: two from Dublin Borough, four from Dublin South, four from Dublin Fingal and two from Dun Laoghaire-Rathdown. Therefore the sample was geographically spread. Data were obtained for a total of 224 children (140 (62.5%) girls, 84 (37.5%) boys). Activity data via accelerometry was obtained for 152 (67.9%) children (100 girls, 52 boys). The remaining 64 accelerometers were returned with fewer than three days of data (probably because either the child had not worn the device or had interfered with the unit and lost the initial data set up).

Height, weight, waist circumference and fitness data were obtained in 140 girls and 84 boys in a total of 12 schools. Table 1 summarises the descriptive data by gender and age into height, BMI and BMI *z* score, waist circumference and $\text{VO}_{2\text{max}}$. Table 2 presents data by gender and age in minutes each day spent sedentary, in moderate, vigorous and hard activity, and in the sum of vigorous and hard activity. Tables 1 and 2 also present the difference between the genders for the described variables (last row in each). When heights of children were divided into centiles using the British 1990 growth reference¹⁸ it was found that 15% of the cohort were above the 97th centile for height and 27% were above the 91st centile. For waist circumference 76% of subjects were above the 75th centile. For BMI 20.7% of girls and 20.2% of boys were overweight, with 6.3% being obese (5% of girls, 8.3% of boys). Figure 1 presents the centiles of height, BMI and waist circumference.

Table 3 details the means of time spent in varying intensities of activity by body composition group (normal, overweight and obese) and gender. To examine activity of at least a vigorous level the time for "vigorous" and "hard" activity were combined. This overall mean vigorous/hard activity score was 64.3 minutes in boys and 37 minutes in girls (table 2). There was a significant difference between the categories of body composition for boys and the time spent in vigorous activity (ANOVA linear trend $p < 0.03$). A significant difference between the genders in overall energy expended in daily physical activity

Table 3 Mean and 95% confidence intervals of activity (minutes) and fitness in boys and girls by body composition

Body composition	Sedentary	Moderate	Vigorous	Hard	$\text{VO}_{2\text{max}}$
Boys					
Normal weight (n=43)	927.9 (900.7 to 955.0)	114.3 (103.9 to 124.7)	39.1 (33.2 to 44.9)	23.9 (18.1 to 29.7)	54.2 (52.8 to 55.6)
Overweight (n=6)	902.5 (864.6 to 940.4)	122.3 (90.4 to 154.1)	40.0 (27.6 to 52.4)	23.9 (18.1 to 29.7)	50.5 (47.6 to 53.4)
Obese (n=3)	1045.5 (933.8 to 1157.2)	58.5 (38.3 to 78.7)	14.0 (11.1 to 16.9)	4.7 (0.7 to 8.7)	46.6 (44.2 to 49.0)
Total (n=52)	935.1* (910.0 to 960.2)	110.5** (100.6 to 120.4)	37.6* (32.3 to 42.9)	22.1 (16.9 to 27.3)	53.2 *** (51.8 to 54.6)
Girls					
Normal weight (n=78)	962.8 (940.9 to 984.7)	96.6 (90.2 to 103.4)	24.4 (22.0 to 26.8)	12.7 (9.9 to 15.5)	49.9 (49.1 to 50.7)
Overweight (n=18)	974.7 (943.6 to 1005.8)	94.4 (80.4 to 108.4)	24.2 (19.0 to 29.4)	9.4 (5.1 to 13.6)	48.4 (47.2 to 49.6)
Obese (n=4)	935.0 (795.3 to 1074.7)	93.0 (73.6 to 112.4)	28.8 (14.4 to 43.2)	12.5 (1.1 to 23.9)	47.7 (44.1 to 51.3)
Total (n=100)	963.8 (945.7 to 981.9)	96.1 (90.6 to 101.6)	24.5 (22.3 to 26.7)	12.1 (9.8 to 14.4)	49.5 (48.8 to 50.2)

Significance for linear trend for body composition divisions-ANOVA.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 4 Correlations between body composition (BMI z score, waist circumference) and $\text{VO}_{2\text{max}}$ with time in minutes spent sedentary, and in moderate, vigorous and hard activity

Variable	Moderate (min)	Hard (min)	Vigorous (min)	Sedentary (min)	$\text{VO}_{2\text{max}}$
BMI (z score)					
All	-0.14	-0.12	-0.06	0.05	-0.27**
Male	-0.42**	-0.17	-0.25	0.22	-0.43**
Female	0.07	-0.09	0.15	-0.06	-0.22**
Waist					
Male	-0.47**	-0.09	-0.31*	0.33*	-0.50**
Female	-0.01	-0.54	-0.07	-0.01	-0.33**
$\text{VO}_{2\text{max}}$					
All	-	0.21**	0.23**	-0.12	-
Male	-	0.26	0.22	-0.14	-
Female	-	-0.11	-0.10	-0.12	-

* $p < 0.05$, ** $p < 0.01$.

-, indicates no correlation analysis undertaken.

was evident (mean boys 562.88 kcal (512.5 to 613.3), girls 453.4 kcal (424.8 to 481.96) ($p < 0.0001$).

Table 4 presents the correlations and level of significance between body composition (BMI as measured by z score and waist circumference), fitness and minutes spent in sedentary, light, moderate, vigorous and hard physical activity. The results suggest that there were significant positive correlations between waist circumference and time spent sedentary in boys ($p < 0.05$), and time in both hard ($p < 0.01$) and vigorous activity ($p < 0.01$) and $\text{VO}_{2\text{max}}$ in both genders. Significant negative correlations were found between time in vigorous activity and waist circumference in boys ($p < 0.05$), but not girls, and this difference was found to be significant ($p < 0.05$). There were significant inverse correlations between $\text{VO}_{2\text{max}}$ and waist circumference ($p < 0.01$) and between $\text{VO}_{2\text{max}}$ and BMI ($p < 0.01$) in both boys and girls.

Table 5 gives the regression coefficients from multiple regression analyses for various dependent variables. These include cardiorespiratory fitness, energy expended in physical activity, time in the following: moderate/vigorous activity, vigorous activity and sedentary. In all cases the model included age, gender, BMI z score and waist circumference adjustments.

DISCUSSION

Objective measurement of physical activity using the RT3 permitted measurement of the time spent in different intensities of activity as well as time spent sedentary in a large random sample of subjects. To the authors' knowledge this is the first study to investigate the relationship between time spent in various intensities of activity and body composition and fitness in children.

Body composition

The children in this study were compared with 1990 British growth references.¹⁸ When height was compared with these

standards it was found that 48% of subjects were above the 75th centile. It would therefore seem that the present British Growth Standards, which are 15 years old, may underestimate height, and this conclusion is supported by other data from a UK study.²⁷

Of the 224 children, 46 (20.5%) were found to be overweight and 14 (6.3%) were obese by BMI criteria. These figures are slightly higher than those for children of the same age in Poland and France, where 15.4% of children were overweight and 3.6% were obese and 18.1% were overweight and 3.8% obese, respectively.²⁸ A recent publication from the 1970 British birth cohort study found that 4.3% of 10-year-olds were obese in 1980 and 16.3% of 30-year-olds were obese in 2000.²⁹ Evidence from this study suggests that use in children of the BMI as the sole identifier may substantially underestimate the incidence of overweight. However, the measure was necessary in order to categorise subjects as of normal weight, overweight or obese. Although 31% of the subjects in this study, had a BMI above the 75th centile, 76% had a waist circumference above the 75th centile.

Physical activity and inactivity

The results show that boys engaged in a mean of 64.3 minutes of hard/vigorous activity each day, whereas the mean time spent in such activity in girls was 37 minutes each day. Boys were found to spend more time in moderate and vigorous activity than girls, but there was no difference between the sexes in the time spent in hard activity or time spent sedentary. It is difficult to compare directly these findings with those of other studies owing to differences in the method of measurement of physical activity, but previous investigations have also found that girls perform less overall and vigorous activity than boys.^{30 31} Although an examination of any difference in physical activity between weekdays and weekend days was not an

Table 5 Multiple regression analysis for various models adjusting for age, gender, BMI and waist circumference

Model	Age	Gender	BMI (z score)	Waist (cm)
Cardiorespiratory fitness	-0.17	-3.82 (0.5)***	-1.12 (0.2)***	0.22 (0.04)***
Energy expended in physical activity	-0.12 (0.2)***	-108.3 (25)***	50.4 (10.1)***	7.3 (1.8)***
Time in moderate/vigorous activity	-8.7 (7.9)	-42.7 (8.5)***	-3.8 (3.3)	-1.1 (0.6)*
Time in vigorous activity (log)	-0.12 (0.1)	0.5 (0.1)***	-0.02 (0)	-0.01 (0.01)
Time sedentary	30.6 (14.5)*	-32.4 (15.6)*	2.95 (6.1)	1.3 (1.1)

Non-standardised B coefficient (SE) and level of significance where applicable.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

What is known about the topic

Few studies have investigated the influence of the time spent in specific intensities of activity on body composition in children.

What this study adds

- The time spent in specific intensities of activity is related to BMI and waist circumference in boys but not in girls.
- In both genders fitness was related to body composition.

objective of the study, it was found that there was no significant difference in energy expenditure at these times.

The examination of body composition and time spent in vigorous activity yielded interesting results. In boys there was a significant difference between the three divisions of body composition (normal, overweight and obese) and time spent in vigorous activity, and a negative correlation between BMI and time spent in moderate activity. In girls, by contrast, there was no significant relationship between body composition and activity measures. This result is similar to a study in a younger age group, in which overweight boys were significantly less active than normal weight boys, but no differences were seen in girls.¹³

The relationship between waist circumference and activity also demonstrated gender differences. There were significant negative correlations between waist circumference and minutes spent in vigorous activity and moderate activity in boys but not in girls. Furthermore, a significant positive correlation between waist circumference and time spent sedentary was seen in boys only. In this context, it is of interest that Rush *et al* found that physical activity was inversely correlated with body fat in boys ($r = -0.43$, $p = 0.006$) but not in girls.¹⁴

Physical fitness and body composition

Physical fitness was higher overall in boys than girls, and in boys there was a significant difference between the three divisions of body composition and fitness. BMI z scores were negatively correlated with fitness in both genders, as was waist circumference and fitness. There were significant correlations between time spent in hard or vigorous activity and fitness in both boys and girls.

Clinical implications of the findings

One of the clinical implications of these findings is that BMI alone has limitations for assessing overweight and that relatively simple measures such as waist circumference, and perhaps fitness, may give a clearer picture of health risk. Janssen *et al* have provided additional evidence that a combination of BMI and waist circumference needs to be used to measure the presence of cardiovascular risk in children and adolescents.³² The high incidence of excessive waist circumference that was found in both genders is of concern because central fat carries a risk of metabolic consequences.³³ As fitness is related to body composition in both genders, regular assessment of fitness of individual boys and girls should be encouraged in schools. Recent studies reported that fit but obese children had similar levels of inflammatory measures as lean unfit children³⁴ and that fitness was inversely correlated with the proinflammatory marker C reactive protein in boys but not in girls.³⁵ This finding, together with the evidence from our study, suggests that the effects of activity on body composition differ between girls and boys.

The findings in relation to the amount of time spent in at least moderate intensity activity (boys greater than 114.3 minutes and girls greater than 96.6 minutes each day) in children of normal weight may be considered in light of recent work by Tudor-Locke *et al*.³⁶ The aim of the latter study was to establish preliminary criterion referenced standards for physical activity in children related to healthy BMI (as indicated by international cut-off points) and their results suggest that 120 minutes of activity each day for girls and 150 minutes of activity each day for boys are needed.

Limitations

Despite the value of accelerometers for the objective measurement of physical activity in children the high failure rate that occurred in this study emphasises the vulnerability of these units to subject interference and children forgetting to wear the device. It might be argued that the need for parental agreement and consent might have also led to bias, with those parents more committed to physical activity agreeing to their child's participation. This is a limitation to any such study. A further limitation may be the use of the specific cut-off points for the definition of each activity intensity. However, although each band contains a large range of movement counts it does permit some classification of activity, which cannot be done with other physical activity measures.

CONCLUSION

Boys were found to take part in more than one hour of vigorous/hard daily physical activity, whereas girls spent about half this time. However, while the time spent in various intensities of activity correlated with markers of body composition in boys, no such correlation was seen in girls. Significant correlations were found between time spent in hard or vigorous activity and fitness in both boys and girls. The evidence for a different relationship between body composition and activity components in girls and boys requires further investigation.

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Figure 1 Christopher Bladin.