# PHYSICAL ACTIVITY, AEROBIC FITNESS, BODY COMPOSITION AND ASTHMA SEVERITY IN CHILDREN AND ADOLESCENTS

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## Statement of Sources Declaration

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All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committees (where applicable).

This project was completed in collaboration with staff from the Respiratory Laboratory at the Royal Children's Hospital, Melbourne.

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# Summary

The investigations described in this thesis were conducted in order to increase the understanding of the relationships between physical activity, aerobic fitness, body composition, asthma, and asthma severity in children and adolescents. This was largely achieved by examining the aforementioned factors in a sizeable population of Melbourne school children and adolescents. However, during the course of the school-based testing, it became apparent that the severe asthmatic category was under-represented, typical of the current literature. Thus, effort was also directed at addressing this knowledge gap by examining a severely asthmatic cohort in a laboratory-based setting. The outcomes generated by these investigations can be summarised as follows:

1) In ‘school-tested’ youth aged 10 to 14 years, prevalence rates of overweight and obesity were 19.1% and 4.0%, respectively. Approximately 16% of participants also suffered from asthma. These rates appear to be representative of similarly aged children and adolescents within Australia. The latter observation also adds weight to the view that asthma prevalence has attenuated in recent years. In addition, overweight and obesity were more prevalent in asthmatics than non-asthmatics, supporting the proposed notion of an asthma-obesity association.

2) Asthmatic and non-asthmatic young people had comparable aerobic fitness and daily physical activity levels and the severity of disease did not influence aerobic fitness nor involvement in physical activity. Males possessed greater aerobic fitness and physical

activity levels and had a lower percentage body fat compared to age-matched females, independent of asthma status (i.e. asthmatic or non-asthmatic).

3) There was a significant inverse relationship between aerobic fitness and markers of increased body fat among non-asthmatic children and adolescents, even after corrections to aerobic fitness were made for fat free mass. Differences in daily physical activity could only partially explain this association. In fact, the current findings suggest that decreased levels of daily physical activity are not the cause of the increased overweight/obesity prevalence among this sample, and that physical activity lacks a strong link to paediatric overweight/obesity in this population. These findings were also present in asthmatic youth.

4) Severely asthmatic youth, premedicated with bronchodilator, had aerobic fitness levels comparable to their non-asthmatic and less severe asthmatic peers. This finding indicates that severely asthmatic youngsters should be able to train at work intensities sufficient to bring about improvements in cardio-respiratory fitness without any added functional limitation due to their condition. In addition, a state of well-controlled asthma (as were the severe asthmatics in this study) afforded the participants the ability to engage in similar levels of physical activity as their non-asthmatic or less severe asthmatic peers. In agreement with data from the 'school-tested' asthmatics, a significantly greater proportion of severely asthmatic participants were overweight or obese in comparison to their non-asthmatic peers.

These findings (i) highlight the association between aerobic fitness and overweight/obesity; (ii) suggested that decreased levels of daily physical activity were not associated with the increased overweight/obesity prevalence in a youth sample within Australia; (iii) emphasize that well-controlled asthmatic young people can undertake levels of physical activity and achieve cardio-respiratory fitness similar to that of their non-asthmatic peers, independent of asthma severity, and; (iv) indicated that asthma is either a risk factor for overweight and obesity or that overweight and obesity may precede asthma.

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## List of Publications & Conference Presentations

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3. **L Welsh**, JG Kemp & RGD Roberts (2004). Fitness and physical activity in asthmatic children: a review. *Sports Medicine* 34 (13): 861-70.
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## List of Abbreviations

| Abbreviation | Definition |
|---|---|
| %BF | Percentage Body Fat |
| 6MRD | Six Minute Running Distance |
| 6MRD/FFM | Six Minute Running Distance per Kilogram Fat Free Mass |
| 6MRT | Six Minute Running Test |
| ANOVA | Analysis of Variance |
| ASQ | Asthma Severity Questionnaire |
| BIA | Bioelectrical Impedance Analysis |
| BIA %BF | Percentage Body Fat derived by BIA |
| BMI | Body Mass Index |
| bpm | Beats per minute |
| DEXA | Dual Energy X-Ray Absorptiometry |
| EIA | Exercise Induced Asthma |
| FER | Forced Expiratory Ratio |
| $FEV_1$ | Forced Expiratory Volume in One Second |
| FFM | Fat Free Mass |
| FM | Fat Mass |
| FVC | Forced Vital Capacity |
| GXT | Graded Exercise Test |
| IL | Interleukin |
| kJ | Kilojoule |
| MET | Metabolic Equivalent |
| MVV | Maximal Voluntary Ventilation |
| PAQ-C | Physical Activity Questionnaire for Children |
| RER | Respiratory Exchange Ratio |
| SS %BF | Percentage Body Fat derived from the Sum of Skinfolds |
| TNF$\alpha$ | Tumour Necrosis Factor Alpha |
| $\dot{V}CO_2$ | Volume of Carbon Dioxide Production |
| $\dot{V}E$ | Minute Ventilation |
| $\dot{V}O_2$ | Oxygen Consumption |
| $\dot{V}O_2max$ | Maximal Oxygen Consumption |
| $\dot{V}O_2max$ | Maximal Oxygen Consumption |

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# Chapter 1 Introduction and Literature Review

## 1.1 Introduction

Evidence-based research shows physical activity and aerobic fitness are positively associated in adults (Blair *et al.*, 1989; Young & Steinhardt, 1993; Anderson & Haraldsdottir, 1995). However, this relationship is less definitive in children and adolescents. In fact, a review of data relating physical activity to aerobic fitness in youth shows similar amounts of support both for and against a relationship (Morrow & Freedson, 1994). Although most studies within the review by Morrow and Freedson (1994) used self-reporting methods to assess physical activity, more recent investigations employing objective methods such as heart rate monitoring and accelerometry have also returned conflicting outcomes (Boreham *et al.*, 1997; Katzmarzyk *et al.*, 1998; Rowlands *et al.*, 1999; Ekelund *et al.*, 2001; Dencker *et al.*, 2006). While debate continues on the nature of the relationship between activity and fitness in children and adolescents, regular physical activity has been associated with greater cardiorespiratory fitness (Mirwald *et al.*, 1981; Rowland, 1996), as well as a number of other health benefits including improved ventilatory capacity (Åstrand & Rodahl, 1986) and lowered serum cholesterol (Cunnane, 1993), lower blood lipids (Tolfrey *et al.*, 1998), lower risks of a cluster of cardiorespiratory risk factors (Boreham & Riddoch, 2001; Andersen *et al.*, 2006) whilst a lack of exercise has been associated with lower levels of cardiorespiratory fitness (National Institutes of Health, 1996), poorer long-term body composition outcomes (Moore *et al.*, 2003) and an increased prevalence of overweight and obesity (Yu *et al.*, 2002).

In a similar fashion, there is also conflicting evidence relating physical activity to overweight and obesity in children and adolescents (Bar-Or & Baranowski, 1994; Ward & Evans, 1995; Goran, 1997; Ward *et al.*, 1997; Rowlands *et al.*, 1999; Ekelund *et al.*, 2001). Uncertainty remains despite a low level of physical activity being suggested as one of the leading causes for the increase in the prevalence of overweight and obesity over the past two and a half decades (Magarey *et al.*, 2001; Yu *et al.*, 2002; Booth *et al.*, 2003).

An excess body mass in children and adolescents may lead directly to a reduction in cardiorespiratory fitness, thereby increasing the risk of morbidity and mortality in adulthood (Cunnane, 1993); again though, the literature concerning this relationship is not consistent. Whereas some groups purport an inverse relationship between adiposity and aerobic fitness in youth (Davies *et al.*, 1975; Nassis *et al.*, 2005), others suggest that the aerobic fitness of overweight and obese youngsters is comparable to their non-obese counterparts when aerobic fitness is normalised for fat-free mass (Elliot *et al.*, 1989; Maffeis *et al.*, 1994).

Interestingly, the prevalences of both asthma and obesity have increased substantially over recent decades in many countries, including Australia (Magnus & Jaakkola, 1997; Magarey *et al.*, 2001). The parallel increases in prevalence has led to the proposal of an asthma-obesity relationship (Tantisira & Weiss, 2001; Ford, 2005; Shore & Johnston, 2006), although the mechanistic basis for such a relationship has not yet been established. Notably, three of four prospective studies among children have demonstrated a significant association between excess body mass and asthma incidence (Chinn & Rona, 2001;

Gilliland *et al.*, 2003; Gold *et al.*, 2003). Most importantly, it appears that lifestyle changes common to both conditions, including reductions in exercise involvement may underpin the association (Rowland, 1991; Chinn & Rona, 2001; Lang *et al.*, 2004).

An asthmatic condition currently affects around 20% of Australian youth (Robertson *et al.*, 2004), and a majority of these sufferers experience exercise-induced bronchoconstriction (Johansson *et al.*, 1997; Wilkerson, 1998; Milgrom & Taussig, 1999). The fear of breathlessness associated with exercise-induced bronchoconstriction may be expected to deter many asthmatic children from participating in regular levels of physical activity. Consequently, a common perception is that asthmatic children may have a reduced capacity for exercise. Although a recent review questioned this premise (Welsh *et al*., 2004), such inactivity would likely increase the probability of realising a ventilatory limitation at modest levels of exercise intensity. Considering the sensations associated with reaching such a limitation are typically perceived as unpleasant, a self-limiting cycle of inactivity may be established in asthmatic children. Such a cycle may result in inactive asthmatic children being less prepared than asthmatic children who are routinely more active to cope with a bout of exercise-induced bronchoconstriction. Asthmatic sufferers affected in such a way would be doubly disadvantaged in that their condition is likely to be poorly controlled (Fink *et al.*, 1993) and their prospects for a healthy adult life impaired (National Institutes of Health, 1996; Yu *et al.*, 2002).

Despite the lack of association between aerobic fitness and physical activity in the non-asthmatic paediatric population, the concept of asthmatic children and adolescents having a ventilatory limitation during exercise suggests that a relationship between aerobic fitness and physical activity in this group may be augmented. If there was an initial deficit in aerobic fitness, increasing the level of physical activity would likely result in improvements in aerobic fitness, thereby creating a direct relationship. Clearly, there is a need to elucidate whether asthmatic children and adolescents display deficits in fitness and activity levels.

It is postulated that exercise behaviours in childhood track into adolescence and adulthood (Cunnane, 1993). As such, the early childhood years are likely to be a critical period for the development of lifestyle patterns. However, a better description of the relationships between activity, fitness and body composition throughout childhood and adolescence is required. Moreover, the specific influences that asthma, asthma severity, age and gender have on these relationships also needs elucidation.

A paucity of research has examined the inter-relationships between activity, fitness, body composition, asthma and asthma severity in a large paediatric cohort. Accordingly, the present investigation aims to address these questions. In the following section, the literature describing body composition, physical activity and aerobic fitness relevant to children and adolescents with and without asthma is reviewed.

## 1.2 Body Composition

### 1.2.1 Introduction

The human body consists of several components including fat mass, lean muscle mass, skeletal bone mass and total body water. The proportions of each of these components have important implications for present and future health outcomes including cardiovascular, nutritional and psychological status as well as physical performance capability (Donnelly *et al.*, 1996; Salbe *et al.*, 2002; Ribeiro *et al.*, 2003).

Fat is an essential component of the human body, critical in maintaining normal physiological function and homeostasis. The majority of body fat is stored in adipose tissue in subcutaneous sites, although there is also some deposited around vital organs to play a primarily protective role in the case of trauma (Malina *et al.*, 2004). However, elevated body fat composition is undesirable, given the strong associations to various diseases including coronary heart disease and non-insulin dependent diabetes mellitus (Gidding *et al.*, 2004; Hardy *et al.*, 2004), asthma (Tantisira & Weiss, 2001), some cancers and hypertension (Parsons *et al.*, 1999; Cole, 2002). In addition, a low body fat composition has been associated with cardiovascular disease (Higashi *et al.*, 2003) and osteoporosis (Ravn *et al.*, 1999).

In Australia, the prevalence of overweight and obesity has been recently reported to be between 19 and 25% (Booth *et al.*, 2001; Magarey *et al.*, 2001; Booth *et al.*, 2003; Hesketh *et al.*, 2004). These rates are consistent with studies from other countries which have all shown seemingly inexorable increases in overweight and obesity over recent decades (Popkin & Udry, 1998; Magarey *et al.*, 2001; Viguie *et al.*, 2002; Heude *et al.*, 2003; Popkin & Gordon-Larsen, 2004). The mechanisms responsible for the increases in incidence are not entirely understood; however, it is widely accepted that inactivity and increased dietary fat intake are significant contributors (Parsons *et al.*, 1999).

Accurate measurements of body composition are therefore vital for developing a better understanding of the etiology and pathology of many diseases (including obesity), in conjunction with identifying associated risk factors. An overview of the most commonly used methods is contained in the next section, with a detailed discussion of overweight and obesity to follow.

### 1.2.2 Measures of Body Composition

Physique, or the commonly used 'somatotypes' defined by William Sheldon (Sheldon, 1950), categorise a person's body shape into one of three types. These categories are namely endomorphy, mesomorphy and ectomorphy. The predominance of digestive organs and a rounded curvature encapsulate endomorphy. Mesomorphy is characterised by the predominance of muscle, bone and connective tissues with muscles having clear definition. And ectomorphy is described by fragile builds with poor muscle development and a predominance of surface area over body mass (Malina *et al.*, 2004). However, generic physique categories are not always useful, because researchers are often interested in the quantities of body components such as fat mass (FM) and fat-free mass (FFM).

A multitude of measures are available for the analysis of body composition, including underwater weighing, dual energy x-ray absorptiometry (DEXA), deuterium oxide dilution, sum of skinfolds, bio-electrical impedance analysis (BIA) and body mass index (BMI).

### 1.2.2.1 Multi-Compartment Models

The classic two-compartment model of body composition analysis, which separates the body into FM and FFM employing underwater weighing (see 1.2.2.2) for measurement has now been developed into three- and four-compartment models, which account for additional variables (Withers *et al.*, 1999). Three-compartment models measure FM, fat-free dry mass (using underwater weighing) and total body water via deuterium dilution (see 1.2.2.4). The four-compartment model which is now considered the 'gold standard' measure, assesses FM, total body water, bone mineral mass and the residual mass. Again, underwater weighing and deuterium dilution are used, as is DEXA (see 1.2.2.3) to measure bone mineral mass. Residual mass is assumed to be 1.404 g/cm$^3$ (Allen *et al.*, 1959). The relevant sections of this chapter describe the aforementioned methods and others.

### 1.2.2.2 Hydrodensitometry – Underwater Weighing

This method of measurement involves submerging a subject in a tank of water following a maximal forced expiration. Once submerged, the subject's underwater weight is recorded, allowing body density to be estimated. After corrections are made for water density and residual volume (Withers *et al.*, 1999), body density can be used to calculate percentage body fat (%BF) (Siri, 1956; Brozek *et al.*, 1963). Underwater weighing involves significant co-operation, can be frightening for children, and demands substantial equipment and time requirements. Though more accurate than many of the other methods available (Bray *et al.*, 2002), underwater weighing is expensive, technically awkward and impractical for use in large group field testing (Eisenmann *et al.*, 2004).

### 1.2.2.3 Dual Energy X-Ray Absorptiometry – DEXA

This method involves whole-body scanning while the subject lies in the supine position (Eisenmann *et al.*, 2004). The DEXA machine creates a series of transverse scans by directing thin X-rays systematically across the subject's body, differentiating between bone, soft tissue FFM and FM. The mass of these three variables can then be calculated.

In a study of 12 young adults, DEXA was performed on five occasions and found to have a relative error of 0.8% for total body bone mineral density and 1.5% for lean body mass. The authors concluded that DEXA provides a precise body composition analysis with a low radiation exposure (Mazess *et al.*, 1990). In fact, DEXA is well accepted as a highly accurate technique for the assessment of body composition (Lohman, 1992; Goran *et al.*, 1996; Salamone *et al.*, 2000; Eisenmann *et al.*, 2004). Although DEXA is highly reliable and accurate, its lack of mobility, low-dose radiation, and high cost render this method generally unsuitable for large population studies.

### 1.2.2.4 Hydrometry – Deuterium Oxide Dilution

The measurement of deuterium dilution provides an accurate estimation of total body water. As previously described, total body water is used in the three- and four-compartment body composition assessment methods. Deuterium dilution requires subjects to provide a baseline saliva sample then consume a dose of around 0.3 g deuterium /kg body mass, to measure the turnover of body water. Salivary enrichment is typically measured by comparing the baseline sample with the average of the samples collected at two and three hours post-dose with a mass spectrometer.

### 1.2.2.5 Sum of Skinfolds

This method involves the measurement of subcutaneous adipose tissue thickness at selected sites using a device such as the Harpenden skinfold calipers (British Indicators Ltd, St Albans, Hertfordshire) – see Figure 1.1 (Appendix J, Chapter 1 Appendices). Typical measurements include the biceps, triceps, subscapular and suprailiac skinfold thickness sites (Durnin & Rahaman, 1967) – see Figure 1.2 (Appendix J, Chapter 1 Appendices). The equations of Siri *et al.* (1956) and Durnin and Rahaman (1967) can be combined to calculate %BF, but population specificity precludes broad acceptance of %BF results.

Numerous studies have reported the sum of skinfolds method to be an accurate predictor of body fat (Houtkooper *et al.*, 1989; Clark *et al.*, 1993; Chan *et al.*, 1998; Bedogni *et al.*, 2003; Eston *et al.*, 2005). For example, a study of 8 to 12-year old children reported no significant difference in %BF values as calculated from magnetic resonance imaging and the sum of skinfolds technique (Chan *et al.*, 1998). Moreover, in a study of 129 African American and Caucasian boys and girls aged 10 to 12 years, the comparison of the four-compartment model (27.8%) and skinfold derived (26.9%) %BF values using the Pennington optimal skinfold thickness model (Bray *et al.*, 2001) returned an $R^2$ value of 0.85 (Bray *et al.*, 2001). Among the same cohort, an $R^2$ value of 0.85 was also found when comparing the %BF values from the four-compartment model and an alternative skinfold equation (Slaughter *et al.*, 1988).

With a high degree of mobility and accuracy, the sum of skinfolds technique is a highly useful method for estimating %BF in the field. However, there are two main arguments associated with its use. One is the idea that skinfold equations are often population specific and inapplicable to other populations or even other samples of the same population. The other major argument relates to the various technical sources of error including skinfold measurement technique, skinfold site location, skinfold caliper, inter-operator variability, and skinfold compressibility, which can lead to prediction errors (Lohman, 1981; Lohman, 1992). Once technical errors are minimised through accredited training and practice, the reporting of skinfolds and measurement errors are well accepted.

### 1.2.2.6 Body Mass Index – BMI

Body Mass Index (BMI) is calculated as weight (kg)/height$^2$ (m) and is used to estimate a person's body fatness. Within acknowledged limitations, BMI is an internationally recognised approach for classifying body composition into normal weight, overweight and obese groups (Pietrobelli et al., 1998; Cole et al., 2000; Hall & Cole, 2006).

Based on BMI data from Brazil, Hong Kong, the Netherlands, Singapore and the United Kingdom, age and gender-specific BMI cut-off points are provided at 6-monthly intervals ranging from 2 to 18 years for normal weight, overweight and obesity (Cole *et al.*, 2000) – see Figure 1.3 (Appendix J, Chapter 1 Appendices). Age and gender-specific cut-off points for %BF based on these BMI cut-off points have also been developed (Taylor *et al.*, 2002) – see Figure 1.4 (Appendix J, Chapter 1 Appendices).

A validation study of BMI in 198 children and adolescents aged 5 to 19 years reported BMI was strongly associated with %BF estimated by DEXA, with $R^2$ values of 0.85 for boys and 0.89 for girls (Pietrobelli *et al.*, 1998). Moreover, an International Obesity Task Force workshop on the most appropriate measures of obesity in youth concluded that BMI "offered a reasonable measure with which to assess fatness in children and adolescents" (Dietz & Bellizzi, 1999).

Reporting BMI does have inherent limitations. These include an inability to accurately estimate body fat in some populations such as people with; a high degree of muscle mass, edema or muscle wasting. However, the simplicity of the BMI, along with its strong associations to %BF, make it practical and relevant calculation for classifying body composition in the field.

### 1.2.2.7 Bio-Electrical Impedance Analysis – BIA

The BIA measures the amount of bioresistance in the body to determine %BF. Bioresistance is an indication of a person's conductivity. Lean tissue is conductive, thereby having a low bioresistance, whilst fat tissue is less conductive due to its low water content. For this reason, a person with a low bioresistance (for their height, weight and gender) will therefore have a low %BF. The opposite also holds true for high bioresistance values. In practice, a BIA unit transmits a low-level current (50 kHz) through the subject's body, allowing values of bioresistance and %BF to be calculated (Biodynamics Corporation, 2000). Unlike underwater weighing, a precise formula for the BIA has never been available.

Nevertheless, the use of BIA in the field has been supported by some researchers (Boot *et al.*, 1997; Casanova Roman *et al.*, 2004), while others have cast doubt over the accuracy of the method (Bray *et al.*, 2002; Fors *et al.*, 2002; Eisenmann *et al.*, 2004).

Casanova Roman *et al*. (2004) tested the reliability of a BIA device in 365 healthy children aged 6 to 14.9 years and found intraclass correlation coefficients of 0.948 for boys and 0.945 for girls. In support, Boot *et al*. (1997) reported a correlation coefficient of 0.99 between lean body mass estimated by BIA and lean tissue mass estimated by DEXA in 403 healthy Caucasian Dutch children. In contrast, a validation study comparing several methods for the assessment of body fat among 114 children reported BIA significantly underestimated %BF in comparison the underwater weighing method (Bray *et al.*, 2002). Moreover, in a study of 61 healthy children aged 10.9 to 13.9 years, BIA overestimated fat mass in lean subjects and underestimated fat mass in overweight subjects in comparison to values obtained by DEXA (Fors *et al.*, 2002). Furthermore, a study of 75 children aged 3 to 8 years reported a low correlation coefficient for %BF estimated by DEXA and BIA (r = 0.30), and concluded that BIA significantly underestimated body fatness as determined by DEXA (Eisenmann *et al.*, 2004).

### 1.2.3 Overweight and Obesity

#### 1.2.3.1 Introduction and Definition

Childhood overweight and obesity have reached epidemic proportions and their prevalence in Australia appears to be increasing (Booth *et al.*, 2003). Other developed countries including the United States (Ogden *et al.*, 2006; Wyatt *et al.*, 2006) and the United Kingdom (National Audit Office, 2001) have also identified similar increases in overweight and obesity among children. Alarmingly, there are approximately 22 million overweight children aged less than 5 years worldwide (Deckelbaum & Williams, 2001).

Obesity in childhood is an independent risk factor for adult obesity and all its associated health problems (Dietz, 1986; Must, 1996). Importantly, it has been estimated that 80% of obese adolescents become obese adults (Schonfeld-Warden & Warden, 1997; Magarey *et al.*, 2003). Moreover, childhood obesity is associated with increased cardiovascular mortality and morbidity, regardless of adult weight (Mossberg, 1989). Evidently, childhood and adolescence are critical periods for the development of adult health status. Put simply, overweight and obesity are an excess of body fat. However, this simple definition immediately raises two important questions - how is body fat measured and what set of cut-off points are used to define ‘excess’? As described earlier in this chapter, numerous measures are available for assessing body composition. Among adults, body fat is commonly assessed by BMI with internationally recognised cut-off points in reference to normal weight, overweight and obesity. These are 18.5-24.99 kg/m$^2$, 25.0-29.99 kg/m$^2$ and >30.0 kg/m$^2$, respectively (Lohman, 1992). However, these definitions cannot be applied to children and adolescents due to the normal growth and maturational-related changes in body fat and size. As such, age and gender-specific BMI cut-off points have recently been developed for people aged 2 to 18 years (Cole *et al.*, 2000) along with age and gender-specific cut-off points for %BF (Taylor *et al.*, 2002) based on the BMI cut-off points of Cole *et al*. (2000).

#### 1.2.3.2 Natural History of Adiposity

In the growing child, changes in body fat mass occur in two ways; firstly, through changes in the number of fat cells or ‘adipocytes’, and secondly, through changes in the mean size of adipocytes (Cole, 2002). In infancy, adipocyte enlargement contributes most to the increasing fat mass, while after infancy fat mass gain arises primarily through cell proliferation (Williams, 2005). Consequently, fat mass rises steeply during the first year of life then falls again, with a second rise later in childhood at around six to seven years of age (Williams, 2005); which is sometimes referred to as adiposity rebound and early onset may or may not be related to childhood obesity (Dietz, 1997; Kroke *et al.*, 2006). This second rise is also a critical period for the development of overweight and obesity in later life (Schonfeld-Warden & Warden, 1997). A systematic review (Parsons *et al.*, 1999) identified several risk factors for the development of later obesity, including physical activity, genetic, psychological and dietary factors, and the timing or rate of maturation. Inevitably, the development of excess mass is a multi-factorial condition which can result in numerous detrimental health effects in childhood and adulthood. However, in basic terms, the development of excess body mass is a result of an energy imbalance – specifically, energy intake outweighs energy expenditure.

### 1.2.3.3 Prevalence of Overweight and Obesity in Australia

In Australia, overweight and obesity reportedly affects around 1 in every 5 children (Booth *et al.*, 2001; Hesketh *et al.*, 2004), with the prevalence appearing to be ever increasing. Using the BMI cut-off points of Cole *et al.* (2000), Magarey *et al.* (2001) investigated the prevalence of overweight and obesity in Australian children and adolescents using data from 1985 and 1995. In 1985, 9.3% of boys and 10.6% of girls were overweight, while 1.4% and 1.2% of boys and girls were obese, respectively. Ten years later, the prevalence of overweight in boys and girls had increased to 15% and 15.8%, respectively, whilst obesity had also increased to 4.5% of boys and 5.3% of girls.

Magarey *et al.* (2001) concluded that the secular trend of increasing overweight and obesity was a major public health concern.

In a more recent study, Booth *et al.* (2003) examined data from five independent research articles to track the changes in prevalence of overweight and obesity in Australian children between 1969 and 1997. The New South Wales Schools Fitness and Physical Activity Survey (1997) and the Health of Young Victorians Study (1997) were used. In addition, data collected in South Australia during the Australian Youth Fitness Survey (1969) was incorporated along with data from the Australian Health and Fitness Survey (1985) and the South Australian Schools Fitness and Physical Activity Survey (1997). Again, the BMI cut-off points of Cole *et al.* (2000) were employed. Data showed that between 1985 and 1997, the combined prevalence of overweight and obesity doubled and that of obesity alone trebled among young Australians.

#### 1.2.3.4 Physical Activity

In growing children, energy intakes must be chronically greater than energy expenditures and total substrate oxidation, though not necessarily on a daily basis, to facilitate normal growth. Hence, overweight and obesity can be viewed as an 'overgrowth' of the adipose tissue normally synthesized to achieve normal body composition (Cole, 2002).

Several energy balance studies show obese children and adolescents consume more food energy than their lean counterparts (Johnson *et al.*, 1956; Wilkinson *et al.*, 1977; Elliot *et al.*, 1989). Moreover, a number of studies assessing the qualitative aspects of diet have demonstrated that obese children prefer diets rich in lipid (Livingstone *et al.*, 1992; Maffeis *et al.*, 1994; DeLany *et al.*, 1995). However, it appears that overweight and obese children may not have significantly lower energy expenditure in comparison to normal weight peers. While a number of studies have reported overweight and obese children and adolescents to be less active than their normal weight peers (Bullen *et al.*, 1964; Ekelund *et al.*, 2002; Salbe *et al.*, 2002), physical activity-related energy expenditure has been consistently reported to be significantly greater among overweight and obese children (Maffeis *et al.*, 1994; DeLany *et al.*, 1995; Maffeis *et al.*, 1996; Ekelund *et al.*, 2002). A factor which has likely clouded the assessment of physical activity among the overweight and obese is that some studies have approached physical activity as a behavioural phenomenon, while others have measured energy expenditure, the physiologic corollary of physical activity. Presently, the uncertainty surrounds whether the current epidemic developed as a consequence of increased energy intake and/or decreased energy expenditure (Jeffery, 2001). However, it is clear that many opportunities for children to lead sedentary lives are available (ACNielsen Media International, 2001) and low physical activity participation may be a key risk factor for the development and maintenance of overweight and obesity (Parsons *et al.*, 1999).

#### 1.2.3.5 Health Consequences

Obesity is considered a major modifiable risk factor for cardiovascular disease and is strongly linked to morbidity and mortality in a wide variety of chronic diseases including heart disease, hypertension, stroke, type 2 diabetes and cancer in adulthood (Parsons *et al.*, 1999; Cole, 2002). Moreover, the prevalence of the metabolic syndrome increases with worsening obesity (Eisenmann, 2003; Weiss *et al.*, 2004). Specifically, Weiss *et al*. (2004) showed that for each half-unit increase in BMI, there was an increased risk of the metabolic syndrome among overweight and obese subjects (odds ratio, 1.55; 95 % confidence interval, 1.16 to 2.08). In addition, around 50% of severely obese youngsters displayed the metabolic syndrome (Weiss *et al.*, 2004).

Obese children and adolescents have also been reported to have significantly lower aerobic fitness and muscular strength (Armstrong *et al.*, 1991; Rowland, 1991), low self-esteem and self-worth (French *et al.*, 1996), a higher incidence of obstructive sleep apnoea (O'Brien *et al.*, 2006) and increased asthma symptoms (Schachter *et al.*, 2003; Wickens *et al.*, 2005). As expected, a direct association exists between the severity of an individual's obesity and the likelihood of complications occurring (Must, 1996; Ebbeling *et al.*, 2002; Weiss & Caprio, 2005). It is probable, however, that the most common physiological consequences of childhood and adolescent obesity will not become apparent until adulthood. In adults, some other commonly found abnormalities include increased plasma lipid levels, hyperinsulinism, increased cholesterol synthesis, and a high frequency of gallstones (Dietz, 1989). However, the most frequently occurring adverse outcomes in adulthood are coronary heart disease and non-insulin dependent diabetes mellitus (Blair & Church, 2004), both contributory to premature mortality.

## 1.3 Asthma

### 1.3.1 Introduction and Definition

Despite attempts for consensus, there is currently no globally accepted "gold standard" definition of asthma. According to West (1998), asthma is characterised by increased airway hyper-responsiveness to varied stimuli and is manifested by widespread narrowing of the airways that changes in severity, either spontaneously or as a result of treatment. Another definition stated that "asthma is a chronic inflammatory disorder of the airways in which many cells play a role, including mast cells and eosinophils. In susceptible individuals, this inflammation causes symptoms which are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment, and also causes an associated increase in airway responsiveness to a variety of stimuli" (Sheffer, 1992). Additionally, asthma is defined by the 1997 National Asthma Education and Prevention Program as a "Chronic inflammatory disorder of the airways in which many cells and cellular elements play a role, in particular; mast cells, eosinophils, T lymphocytes, macrophages, neutrophils, and epithelial cells" (National Asthma Education and Prevention Program, 2002). Additonally, the guideline also states inflammation causes recurrent episodes of wheezing, breathlessness and chest tightness that are associated with widespread but variable airflow obstruction, and this inflammation leads to an increase in airway hyper-responsiveness to a variety of stimuli or triggers.

### 1.3.2 Pathology and Triggers

A typical asthmatic airway has hypertrophied smooth muscle that contracts during an asthmatic episode, resulting in bronchoconstriction. Additionally, asthmatic airways are characterized by hypertrophy of mucus glands, edema of the bronchial wall and widespread infiltration by eosinophils. The mucus possesses a thick consistency and, in severe cases of asthma, many airways are occluded due to mucous plugging, some of which may be coughed up in sputum (Cotes, 1993; West, 1998). In uncomplicated asthma, a destruction of the alveolar walls is not observed and neither are there copious amounts of bronchial secretions. On occasion, the large quantity of eosinophils in the sputum gives a purulent appearance, which may be wrongly attributed to infection (Cotes, 1993; West, 1998). A variety of triggers stimulate airway obstruction in asthma. Among the most frequent are allergens (including house dust mite, cat and dog dander), infections, emotions, cold air, physical activity, and air pollution such as environmental tobacco smoke (National Heart, Lung and Blood Institute, NHLBI, 2003). For these reasons, the identification of triggers that evoke asthma in an individual child or adolescent is central to the diagnosis and management of their disease.

### 1.3.3 Pathogenesis

Two features are common to all asthmatics – airway hyper-responsiveness and airway inflammation (Werner, 2001). Eosinophils, mast cells, neutrophils, macrophages and basophils have been associated with these two classic features (Varner & Busse, 1999). Inflammatory mediators including histamine, leukotrienes and platelet-activating factor are elevated in asthmatic airways, blood and urine (Gaston, 1998). Cytokines are also strongly linked to modulating inflammatory and immune cell function and support the inflammatory response in the airway. The cytokines include; interleukin (IL)-3, IL-4 and IL-5 (West, 1998).

### 1.3.4 Clinical Assessment

Patients with asthma are heterogeneous and present signs and symptoms that vary widely. Typical symptoms include cough, wheezing, shortness of breath (dyspnoea), chest tightness and sputum production. However, the presentation of these symptoms alone cannot confirm a diagnosis of asthma. A detailed medical history, physical examination and pulmonary function testing are all used in a typical clinical assessment for the diagnosis of asthma (National Asthma Education and Prevention Program, 1997). The clinician trying to establish a diagnosis of asthma should determine that episodic symptoms of airflow obstruction are present, the airflow obstruction is at least partially reversible and that alternative diagnoses are excluded. The physical examination should focus on the upper respiratory tract, chest, and skin with pulmonary function testing (spirometry) used to test airway reversibility. The presence of atopic dermatitis/eczema, plus a family history of asthma and allergies, may also assist in diagnosis (National Asthma Education and Prevention Program, 1997). Although no 'gold standard' exists for assessing asthma severity, symptom frequency, exercise tolerance, hospitalisations and current medications can be used.

### 1.3.5 Asthma Severity Assessment

Despite efforts to develop a consensus for the assessment of asthma severity (National Heart Lung and Blood Institute, 1991; National Asthma Education and Prevention Program, 1997), there is still no 'gold standard' protocol/definition for its evaluation. As a result, clinicians and researchers have used a variety of methods to classify disease severity. Wheeze (Rosier *et al.*, 1994), pulmonary function (National Asthma Education and Prevention Program, 1997), medication habits (Lang *et al.*, 2004), hospitalisations and school absenteeism (Szentagothai *et al.*, 1987) have all been used.

In 1994, Rosier *et al.* published a multifaceted parental structured questionnaire for the assessment of asthma severity in children. The parents of 1267 Melbourne school children with wheeze were asked to report on their child's symptoms and restriction of activity due to asthma. The result of this study was a continuous severity scale – the Asthma Severity Questionnaire (ASQ) (Rosier *et al.*, 1994). Study statistics indicated that, in terms of severity, 97% of children were well described by the ASQ. The ASQ also correlated significantly with school absence due to wheeze (r = 0.35), visits to medical care for wheeze (r = 0.22), and the amount of asthma medication used (r = 0.36). In general, the ASQ facilitates a standardised description of the impact that asthma has on the daily life of school children.

### 1.3.6 Spirometry

Spirometry assesses how an individual inhales or exhales volumes of air over a period of time, and is used as a screening test of respiratory health. The most important variables measured in spirometry are volume and flow. Although spirometry cannot lead clinicians directly to a diagnosis, it provides important information about the presence of any restrictive or obstructive lung disease, which can assist clinicians with diagnostic conclusions (American Thoracic Society, 2005).

Fundamental reasons for the use of spirometry include: (a) measuring the effect of disease on pulmonary function; (b) assessing prognosis and; (c) screening individuals at risk of having pulmonary disease.

The key components of spirometry are the forced vital capacity (FVC) and the forced expiratory volume in one second ($FEV_1$). FVC is the maximal volume of air exhaled with maximally forced effort from a maximal inspiration, expressed in litres at body temperature and ambient pressure saturated with water vapour (American Thoracic Society, 2005). The $FEV_1$ is the maximal volume of air exhaled in the first second of the FVC manoeuvre, expressed in litres at body temperature and ambient pressure saturated with water vapour (American Thoracic Society, 2005).

The spirometry test procedure has three distinct phases: 1) a maximal inspiration; 2) a forced exhalation; and 3) a continued complete exhalation to the end of the test, with typical exhalation times for children and adolescents ranging from three to seven seconds (American Thoracic Society, 2005).

### 1.3.7 Asthma Prevalence in Australia

Peat *et al.* (1994) published a serial cross-sectional study examining the changing prevalence of asthma in Australian children. The investigation was conducted in two towns in New South Wales (Belmont and Wagga Wagga), with children aged 8 to 10 years. The first sample was taken in 1982 and the second in 1992. In Belmont, the prevalence of airway hyper-responsiveness increased two-fold over the 10 years to 19.8%, while in Wagga Wagga, a 1.4-fold increase to 18.1% was found. In Belmont, reported wheeze during the previous 12 months had increased from 10.4% in 1982 to 27.6% in 1992, while in Wagga Wagga this parameter increased from 15.5% to 23.1%.

In 1998, Robertson *et al.* published the findings from the Australian arm of the International Study of Asthma and Allergy in Childhood in two target populations of 6 to 7 years and 13 to 14 years of age. The prevalence of wheeze in the past 12 months was 24.6% for the younger children and 29.4 % for the 13-14 year old age group. It was concluded that asthma prevalence in Australian children was continuing to increase and was higher among Australian-born children than children born elsewhere. However, the most recent evidence suggests that asthma prevalence has either undergone a down-turn or reached a plateau, with approximately 20% affected by the disease (Robertson *et al.*, 2004). Some possible explanations for the reduction in prevalence include; increased attendance at childcare facilities (Oddy *et al.*, 2002) and/or a previous over-reporting of wheeze (Jenkins *et al.*, 1996).

### 1.3.8 Exercise Induced Asthma

Exercise induced asthma (EIA), exercise induced bronchoconstriction and exercise induced bronchospasm are terms used to describe the transient airflow obstruction associated with physical activity (Milgrom & Taussig, 1999). Symptoms include shortness of breath, wheezing, chest tightness and cough and usually follow the period of bronchodilatation present in the early stages of exercise (Anderson, 2002). In children, EIA typically occurs within 10 minutes of commencing exercise and peaks around 3 to 5 minutes post-exercise (Xiros *et al.*, 2002). Symptoms normally resolve within 60 minutes (Anderson, 2002).

Between 70 to 90% of asthmatic children are thought to experience EIA (Johansson *et al.*, 1997; Wilkerson, 1998; Milgrom & Taussig, 1999), a phenomenon that could act as a deterrent to exercise. In fact, some evidence suggests that upon receiving a physician's diagnosis of asthma, some individuals may avoid physical activity in order to evade EIA (Mälkiä & Impivaara, 1998). Such inactivity has the potential to result in detrimental health effects such as cardiovascular disease and obesity (Magarey *et al.*, 2001; Yu *et al.*, 2002; Booth *et al.*, 2003). However, many asthma medications can suppress EIA if taken prior to exercise, allowing normal activity (Milgrom & Taussig, 1999).

The mechanisms triggering a bout of EIA are not entirely understood, however, there are two schools of thought. Some researchers believe that EIA is caused by a shift in the osmotic gradient in the airway (Anderson & Daviskas, 2000), whilst others consider thermal changes to be responsible (McFadden, 1990).

### 1.3.8.1 Osmotic Theory

Reasearchers advocating the osmotic theory believe that EIA originates as a consequence of inspiring and conditioning, thereby heating and humidifying, large volumes of air during exercise (Anderson & Daviskas, 2000). The resultant evaporative water loss from the airway mucosal surface causes the airway surface liquid to become hyperosmolar yielding an osmotic gradient. In doing so, the gradient stimulates the movement of water from surrounding epithelial cells into the bronchial region, resulting in cell volume loss (Anderson & Holzer, 2000). This water movement provides the catalyst for the initiation of biochemical events, which include an increase in the intracellular concentration of calcium and inositol triphosphate (Anderson & Holzer, 2000). This stimulus subsequently leads to the release of pro-inflammatory mediators including histamine and leukotrienes from mast cells and eosinophils which activates bronchial smooth muscle contraction, thereby causing airway narrowing (Tan & Spector, 2002).

### 1.3.8.2 Thermal Theory

Proponents of the thermal theory believe that reductions in airway temperature during exercise lead to an increased bronchial blood flow and rapid re-warming of airways after exercise, producing bronchial narrowing (McFadden & Gilbert, 1994). It is proposed that the thermal events associated with exercise cause a reactive hyperemia of the bronchial microvasculature and edema of the airway wall, both contributing to airway narrowing (McFadden & Gilbert, 1994). High ventilation levels in conjunction with cool air inspirates lead to both conductive and convective heat loss from the mucosal surface as the inspired air is conditioned to full saturation at body temperature (McFadden & Gilbert, 1994). The degree of airway temperature reduction is believed to be proportional to the level of ventilation, which consequently affects the degree of bronchial narrowing (McFadden, 1990). That is, the larger the volume of air requiring conditioning, the cooler the airways become, the more rapidly they are re-warmed, and the more the bronchi are narrowed (McFadden & Gilbert, 1994).

### 1.3.9 Obesity and asthma

The overall increase in asthma prevalence over recent decades (Magnus & Jaakkola, 1997) has been paralleled by an insidious rise in the prevalence of obesity in Australian youth (Magarey *et al.*, 2001). Concomitant increases in the incidence of both conditions has resulted in the proposal of an asthma-obesity relationship (Tantisira & Weiss, 2001). Findings from several studies concluded excess body mass is a risk factor for asthma development (Gennuso *et al.*, 1998; Figueroa-Munoz *et al.*, 2001; von Kries *et al.*, 2001; Gilliland *et al.*, 2003; Bibi *et al.*, 2004; Oddy *et al.*, 2004; Schaub & von Mutius, 2005; Wickens *et al.*, 2005). Moreover, several specific mechanisms associate the two conditions of asthma and obesity, including mechanical effects, up-regulated immune responses and fetal programming.

#### 1.3.9.1 Mechanical Effects

Obesity may affect asthma through mechanistic compromises to lung function. In particular, the elevated abdominal content present in obesity can result in a reduced functional residual capacity due to the altered position of the diaphragm (Pelosi *et al.*, 1998; Gibson, 2000). Additionally, obesity has been associated with a reduced tidal volume (Sampson & Grassino, 1983). The combination of a reduced functional residual capacity and low tidal volume infers small cycling rates, which has lead to the proposal of a smooth muscle 'latching' state (Fredberg *et al.*, 1996; Fredberg *et al.*, 1997; Fredberg, 2000). Specifically, the 'latching' hypothesis proposes a conversion of rapidly cycling actin-myosin cross bridges to slowly cycling latch bridges; that is, a reduction in functional residual capacity and tidal volume reduces the amount of muscle strain that occurs with each breath. Less strain results in fewer detachments of myosin from actin and hence a stiffer airway smooth muscle. The stiffer the muscle, the more difficult it is to strain it; the result being airway smooth muscle shortening and consequent reductions in airway caliber (Fredberg *et al.*, 1996; Fredberg *et al.*, 1997; Fredberg, 2000). The latch state has been proposed to be responsible for the persistent airway obstruction seen in many asthmatics (Fredberg *et al.*, 1996; Fredberg *et al.*, 1997) and an increased airway hyper-responsiveness (Fredberg *et al.*, 1996; Fredberg *et al.*, 1997).

Furthermore, both asthma and obesity have strong associations to gastro-esophageal reflux. The estimated prevalence of gastro-esophageal reflux in asthmatic children is around 50-60% (Sontag, 2000), with gastro-esophageal reflux related asthma symptoms thought to be a result of acid induced bronchoconstriction; either by direct microaspiration or by vagally mediated reflux (Patterson & Harding, 1999). Additionally, obesity has been cited numerous times as an independent risk factor for gastro-esophageal reflux and gastro-esophageal reflux symptoms (Locke *et al.*, 1999; Ruhl & Everhart, 1999; Wilson *et al.*, 1999). Mechanically, this effect may be mediated via increased abdominal pressures which increase the gastro-esophageal pressure gradient (Mercer *et al.*, 1987; Zacchi *et al.*, 1991). Consequently, it has been speculated that gastro-esophageal reflux may mediate the relationship between asthma and obesity (Dixon *et al.*, 1999; Dhabuwala *et al.*, 2000).

### 1.3.9.2 Immune Modification

Increasing evidence suggests that, like asthma, obesity is an inflammatory state. Chronic, low-grade systemic inflammation in obese people is characterized by increased circulating leukocytes, and increased serum concentrations of cytokines, cytokine receptors, acute phase proteins, and chemokines (Bullo *et al.*, 2002; Bruun *et al.*, 2003; Bullo *et al.*, 2003; Takahashi *et al.*, 2003). Importantly, there may be an overlap of genes important to both asthma and obesity. Specifically, tumour necrosis factor alpha (TNFα), interleukin 6 (IL-6) and interleukin 1β (IL-1β) have all been associated with the obese state (Hotamisligil *et al.*, 1995; Bunout *et al.*, 1996; Bastard *et al.*, 1999; Visser *et al.*, 1999; Visser *et al.*, 2001). Significantly, the levels of circulating TNFα are increased in asthmatics, with an exposure to allergens producing further increases (Gosset *et al.*, 1992). In addition, elevated levels of TNFα have also been observed in obese mice (Uysal *et al.*, 1997; Uysal *et al.*, 1998). Moreover, IL-6 production is increased in asthmatics (Gosset *et al.*, 1992; Yokoyama *et al.*, 1995) and has been found to be constitutively expressed by adipocytes and correlate with total fat mass (Mohamed-Ali *et al.*, 1997; Tsigos *et al.*, 1999). Furthermore, IL-1β has been associated with increased levels of interleukin 5, one of the primary cytokine mediators of asthma (Tang *et al.*, 1999), and IL-1 β production has been positively correlated with BMI (Bunout *et al.*, 1996). Finally, leptin, a pro-inflammatory cytokine which is produced by adipose tissue has been observed at higher serum concentrations in adults with asthma (Sood *et al.*, 2006).

#### 1.3.9.3 Fetal Programming

Many chronic diseases may stem from fetal adaptations to malnutrition (Barker, 1991). Similarly, the development of asthma and obesity may also be influenced by events occurring *in utero*. For example, low birth weight is associated with increased body fat later in life (Law *et al.*, 1992; Hediger *et al.*, 1998) as well as lower adult lung function (Barker *et al.*, 1991). A small lung size is also a known risk factor for asthma (Gold *et al.*, 2003), and obese mice were observed to have significantly smaller lung mass when compared to age- and gender-matched lean mice (Shore *et al.*, 2003). Subsequent, *in utero* conditions may play a common role in the onset of asthma and obesity.

## 1.4 Physical Activity

### 1.4.1 Introduction and Definition

Physical activity is behaviour which can be undertaken in various forms including free play, planned exercise and even household chores (Malina *et al.*, 2004). As an umbrella term, physical activity has been defined as a complex set of actions which encompasses any bodily movement, produced by skeletal muscles that results in energy expenditure above the resting level (Caspersen *et al.*, 1985).

### 1.4.2 Physical Activity and Health

Expert opinion suggests that physical activity is an important determinant of health status in children and adults, including cardiovascular functioning, skeletal integrity, and psychological well-being (Caspersen *et al.*, 1985; Sallis & Patrick, 1994). For adults, there is a consensus that higher levels of physical activity are associated with a reduced risk of coronary artery disease (Paffenbarger *et al.*, 1986), osteoporotic fractures, hypertension and depression (Baranowski *et al.*, 1992). Importantly, it is now strongly believed that many of the chronic inactivity related diseases seen in adulthood have their origins in childhood and adolescence. Specifically, the younger years are seen as the critical period for the development of lifestyle habits (including physical activity) which are directly related to health status in adulthood (Kemper, 1986; Cunnane, 1993; Anding *et al.*, 1996; Magarey *et al.*, 2003).

Regular participation in physical activity has also been associated with a greater level of cardiorespiratory fitness (Rowlands *et al.*, 1999), improved ventilatory capacity (Åstrand & Rodahl, 1986; Dencker *et al.*, 2006) and a lowered serum cholesterol (Rossi *et al.*, 1994). Conversely, a low level of physical activity has been associated with lower levels of cardiorespiratory fitness (National Institutes of Health, 1996) and has been suggested as a primary cause for the dramatic increase in the prevalence of overweight and obesity in children and adolescents over recent decades (Magarey *et al.*, 2001; Booth *et al.*, 2003).

### 1.4.3 Measures of Physical Activity

The accurate measurement of physical activity is essential for research studies in which physical activity is an outcome or exposure of interest. Moreover, the accurate assessment of physical activity is necessary if the physiologic mechanisms linking physical activity and health are to be completely elucidated. Both subjective and objective methods exist for the measurement of physical activity (Sirard & Pate, 2001). Subjective methods include retrospective questionnaires, interview administered recall and activity diaries, while objective measures include the doubly labeled water technique, accelerometers and heart rate monitoring. Given their cost-effective nature, subjective self-report methods are often the measurement of choice for large-scale epidemiological investigations.

### 1.4.3.1 Doubly Labeled Water

The doubly labeled water technique method, which measures energy expenditure, is currently regarded as the 'gold standard' for assessing physical activity (Ekelund *et al.*, 2002). The technique involves the ingestion of water containing two stable isotopes, namely deuterium and oxygen-18 (Schoeller, 1988). Oxygen-18 is released from the body in the form of carbon dioxide and water whilst deuterium is eliminated in water. "The difference in elimination rate between these two isotopes is a measure of carbon dioxide production" (Trabulsi & Schoeller, 2001). The measure of carbon dioxide production can then be transformed into a value of energy expenditure by employing indirect calorimetry equations. Although doubly labeled water possesses a higher degree of accuracy compared to other measures of physical activity and does not alter normal activity, this form of assessment is expensive and often beyond the resources of many large population research studies.

### 1.4.3.2 Questionnaires

Several questionnaires exist for the measurement of physical activity in children and adolescents (Sallis *et al.*, 1988; Kriska *et al.*, 1990; Aaron *et al.*, 1995; Crocker *et al.*, 1997). The Modifiable Activity Questionnaire for Adolescents was originally developed for the assessment of physical activity in diabetics (Kriska *et al.*, 1990) and was later modified by Aaron *et al.* (1993). The four-question Modifiable Activity Questionnaire for Adolescents attempts to gauge the type, frequency and intensity of physical activity over the previous year as well as the previous 14 days. An example question states "How many of the past 14 days have you done at least 20 minutes of exercise hard enough to make you breath heavily and make your heart beat fast?" (Aaron *et al.*, 1993). The Modifiable Activity Questionnaire for Adolescents was tested for reliability in 100 junior high school males and females aged 15 to 18 years (Aaron *et al.*, 1995). Test-retest *r* values after one month were 0.78 and 0.75 for males and females, respectively, whilst the *r* values after one year were 0.54 and 0.65.

The Seven-Day Physical Activity Recall was originally developed in 1985 (Sallis *et al.*, 1985) and was modified three years later (Sallis *et al.*, 1988). The Seven-Day Physical Activity Recall is an interview-based questionnaire in which the participant is asked to estimate their time spent in physical activity, strength and flexibility activities over the seven days prior to the interview. The Seven-Day Physical Activity Recall was tested for reliability and validity (Sallis *et al.*, 1993) in 102 male and female students from the 5$^{th}$, 8$^{th}$ and 11$^{th}$ grades, who completed the Seven-Day Physical Activity Recall twice within seven days. The test-retest *r* values were 0.47, 0.59 and 0.81 for grade 5, 8 and 11, respectively. Validity was also examined via the relationship between the hours of recalled "very hard" activity and heart rate monitoring time periods ≥ 160 beats per minute. Correlation coefficients of 0.29, 0.45 and 0.72 were found for grades 5, 8 and 11, respectively.

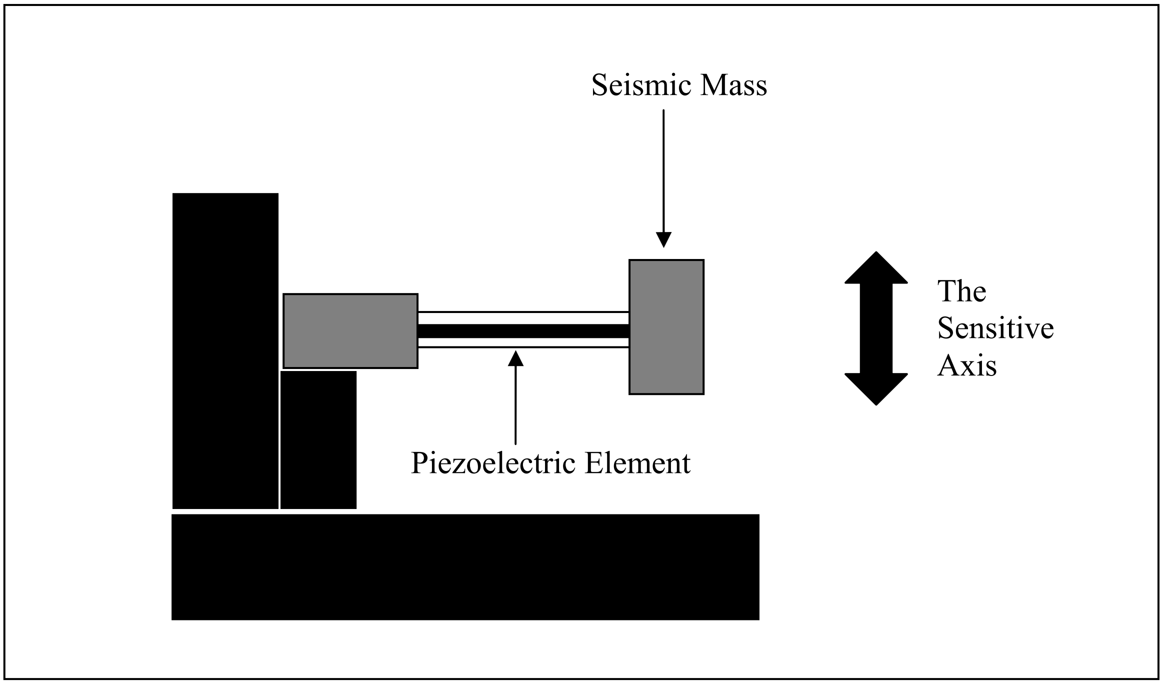
The Physical Activity Questionnaire for Children (PAQ-C) was developed as a 7-day recall questionnaire to rank the frequency, intensity and type of activity that children performed in a regular week (Crocker *et al.*, 1997). Acting on the suggestion that time period memory cues would aid recall accuracy (Baranowski, 1988), the PAQ-C was developed to include memory cues such as 'at recess', 'at lunch', 'after school' and 'in the evening', as well as separating weekday and weekend activity. Kowalski *et al.* (1997) investigated the validity of the PAQ-C by administering the questionnaire to 97 students aged between 8 and 13 years. The PAQ-C was found to be moderately, yet significantly, associated with other measures of physical activity, namely a self-administered physical activity questionnaire (r = 0.41), motion sensors (r = 0.39), an activity recall interview (r = 0.46) and a step test of fitness (r = 0.28). Kowalski *et al.* (1997) also reported that the PAQ-C was useful for large population studies involving children with differing levels of PA. Crocker *et al.* (1997) tested the reliability of the PAQ-C in 84 students ranging in age from 9 to 14 years. The authors reported acceptable levels of test-retest reliability for both males (r = 0.75) and females (r = 0.82) after one week. Crocker *et al.* (1997) proposed that the recall instrument with the best measurement properties was 'probably Sallis' 7-day interview' (Sallis *et al.*, 1993). However, Crocker *et al.* (1997) also commented that such interview methods are moderately expensive and too time consuming to use in research with large sample sizes. Although the PAQ-C is not recommended for use is small studies (Crocker *et al*., 1997), it does not alter an individual's physical activity behaviour, it is cost- and time-effective, is structured with more time period memory cues than other questionnaires available such as the Modifiable Activity Questionnaire for Adolescents, and has demonstrated acceptable repeatability in youth aged 10 to 15 years (Toohey, 2000). It therefore provides a useful method for physical activity assessment in large-scale field research.

#### 1.4.3.3 Accelerometry

Accelerometers are motion sensors that objectively measure body movement accelerations in a given plane or planes (i.e. vertical, horizontal, lateral). Given that acceleration is defined as the change in velocity over time, accelerometers can quantify the volume of activity and the data can then be used to estimate the intensity of the movement. Reliable accelerometers are widely available and although their costs are still quite high, they are not prohibitive. In 1999, accelerometry was still considered to be in the developmental stage (Troiano, 2005) and, as such, the interpretation of accelerometry data remains a challenge due to the gaps and inconsistencies in the calibration and validation literature. Although many accelerometers are not water resistant, and therefore miss activity such as swimming, they provide a continuous objective measurement of physical activity quantity. It should also be noted that a major limitation of most accelerometers is that they can only reliably detect dynamic events, so have a poor sensitivity for more static activities such as weight lifting and cycling. Accelerometers are relatively small and light-weight, making them unobtrusive and practical for extended periods of measurement. Both uni-axial and tri-axial accelerometers are available, with the latter being more expensive. Whereas uni-axial accelerometers measure accelerations in the vertical plane only, tri-axial accelerometers provide measurements in the vertical, horizontal and lateral planes (Chen & Bassett, 2005; Freedson *et al.*, 2005).

### 1.4.3.3.1 Basic Physics and Measurement Principles

Most accelerometers in current use contain piezoelectric sensors that measure accelerations in one to three orthogonal planes. Acceleration is the change in speed with respect to time and is usually measured in gravitational units (G; 1 G = 9.8 $m.s^{-2}$). A piezoelectric acceleration sensor consists of a piezoelectric element and a seismic mass (cantilever beam configuration), enclosed in a housing (Chen & Bassett, 2005) – see Figure 1.5. When a sensor undergoes acceleration, the seismic mass causes the piezoelectric element to encounter deformation in the form of bending. The changes result in a build up of displaced charge on one side of the sensor, which then generates a variable output voltage signal which is proportional to the applied acceleration. The voltage signal, after being filtered and amplified, is then sampled at a pre-determined frequency by the device to convert the analog voltage signal to a digital series of numbers (A/D conversion) known as raw counts. A digital integration algorithm then sums the raw counts for a given time period (epoch), which is usually 60 seconds (Chen & Bassett, 2005).




(Chen & Bassett, 2005)

**Figure 1.5 Schematic of the piezoelectric accelerometer cantilever beam configuration.** A typical piezoelectric acceleration sensor consists of a piezoelectric element and a seismic mass, housed in an enclosure. When the sensor undergoes acceleration, the seismic mass forces the piezoelectric element to deform. The conformational changes generate a voltage output proportional to the acceleration, thereby providing an objective measure of physical activity.

#### 1.4.3.3.2 ActiGraph

The ActiGraph [formerly known as the Computer Science and Applications (CSA) or the Manufacturing Technology, Inc. (MTI)] accelerometer (ActiGraph, LLC, Fort Walton, Florida) is a uniaxial device. The sensor is configured as a cantilever beam and is most sensitive in the vertical plane (Freedson *et al.*, 2005).

Trost *et al.* (1998) conducted the first paediatric validation study of the ActiGraph in 30 children aged 10 to 14 years, using energy expenditure from indirect calorometry as a criterion measure. The subjects performed three five-minute treadmill bouts at 3, 4 and 6 miles per hour, respectively, whilst wearing two ActiGraph model 7164 accelerometers, one on each hip. Meanwhile oxygen consumption was monitored continuously and energy expenditure was determined by multiplying the average oxygen consumption by the caloric equivalent of the mean respiratory exchange ratio. Both accelerometers were sensitive to changes in treadmill speed, and the mean activity counts from each unit were not significantly different. Activity counts from both units were strongly and significantly correlated with energy expenditure ($r = 0.86$ and $0.87$). The authors concluded the ActiGraph monitor was a valid and reliable tool for quantifying treadmill walking and running in children.

In another validation study (Ekelund *et al.*, 2001), 9-year-old children had their energy expenditure estimated using the doubly labeled water technique and wore the ActiGraph monitor for 14 days. Physical activity determined by activity counts was significantly related to energy expenditure ($r = 0.39$, $p<0.05$).

A more recent study of the ActiGraph unit again demonstrated the monitors are an accurate and reliable tool for quantifying changes in acceleration (Metcalf *et al.*, 2002). The 'Early Bird' study tested the ActiGraph monitors for intra- and inter-instrument variability by employing a motorised turntable to control variations in speed. Along with a range of different speeds, the monitors were subjected to varied angles. Where repeatability was concerned, no significant difference could be found between the monitors. A loss of 6% in the mean score was recorded when the monitor was tilted from 0° through to 15°. For the two fixed speeds of fast and medium, the intra-instrument coefficients of variation did not exceed 2%, while the inter-instrument variability remained within 5%.

Freedson *et al.* (1997) developed a regression equation to estimate the metabolic equivalent (MET) from activity monitor counts and age. The equation was based on data gathered from 6- to 18-year old children and adolescents who completed two treadmill walking speeds and one running speed. Gas analysis was measured by indirect calorimetry. Resting energy expenditure was estimated from age-specific prediction equations to derive the metabolic equivalent (MET) at different intensity levels. The resultant equation was:

METs = 2.757 + (0.0015 x activity monitor counts /minute) – (0.08957 x age (decimal years)) – (0.000038 x activity monitor counts /minute x age (decimal years)) (Freedson *et al.*, 1997).

Based on this equation, Trost *et al*. (2002) developed age-specific cut-off points (counts per minute) for defining exercise intensity in METs in children and adolescents. The cut-off points are shown in Table 1.1

**Table 1.1 ActiGraph count cut-offs (counts per minute) for defining exercise intensity in METs, in children and adolescents**

| **Age (years)** | **3 METS** | **6 METS** | **9 METS** |
|---|---|---|---|
| 6 | 614 | 2972 | 5331 |
| 7 | 633 | 3064 | 5495 |
| 8 | 803 | 3311 | 5819 |
| 9 | 913 | 3521 | 6130 |
| 10 | 1017 | 3696 | 6374 |
| 11 | 1135 | 3908 | 6681 |
| 12 | 1263 | 4136 | 7010 |
| 13 | 1399 | 4382 | 7364 |
| 14 | 1547 | 4646 | 7745 |
| 15 | 1706 | 4932 | 8158 |
| 16 | 1880 | 5243 | 8607 |
| 17 | 2068 | 5581 | 9094 |
| 18 | 2274 | 5951 | 9627 |

(Telford *et al*., 2005)

### 1.4.3.4 Heart Rate

Heart rate monitoring for the measurement of physical activity is based on the relationship between heart rate and oxygen consumption ($\dot{V}O_2$) (Gutin *et al.*, 1976; Iannotti *et al.*, 2004). The use of heart rate monitors with full-day storage capacity and 'every minute' recording options are appropriate for quantifying physical activity.

In a study of 19 boys and 17 girls, aged 7, 9, 12 and 15 years, subjects had their total energy expenditure measured simultaneously by doubly labeled water (10-15 day period) and heart rate monitoring (2-3 separate days) (Livingstone *et al.*, 1992). The estimation of heart rate-derived total energy expenditure involved measurements of basal metabolic rate (via indirect calorimtery), resting metabolic rate, individually determined heart rate-oxygen consumption regression lines (via simultaneous recordings of oxygen consumption and heart rate for various activities including an incremental treadmill exercise test), and minute-by-minute day-time heart rate recordings in free-living conditions. At all ages, no significant differences were reported in average heart rate-derived total energy expenditure and average doubly labeled water -derived total energy expenditure, aside from the underestimation of heart rate-derived total energy expenditure in 9-year old subjects ($p < 0.001$). The authors concluded "heart rate monitoring provides a close estimation of the total energy expenditure" and that the "Heart rate method is one of the best-available field techniques for objective assessment of physical activity levels" (Livingstone *et al.*, 1992).

Similarly, a more recent study also examined total energy expenditure using heart rate monitoring and the doubly labeled water technique (Ekelund *et al.*, 2002). Over two 10-

day periods, eight male speed skaters (18.2 ± 1.3 years) had their total energy expenditure measured simultaneously by doubly labeled water and heart rate monitoring (days 1-8). Total energy expenditure values obtained by doubly labeled water were 16.8 ± 3.8 and 16.9 ± 2.9 MJ per day in the two periods, respectively, while total energy expenditure values estimated from heart rate data were 17.1 ± 3.1 and 17.0 ± 2.7 MJ per day, respectively. No differences were observed between these estimates of energy expenditure ($p = 0.44$).

Despite these findings, other reports have cast doubt over the accuracy of heart rate monitors for the estimation of energy expenditure. Rowlands *et al.* (1997) highlighted that heart rate as an indirect estimate of physical activity makes assumptions based on the linear relationship between heart rate and oxygen uptake, which may be erroneous. A heart rate measure is sensitive to emotional stress and body position, but takes longer to reach resting levels after physical exertion compared with oxygen uptake. Furthermore, heart rate monitoring lags behind movement, particularly because children's physical activity is often spasmodic or intermittent in nature (Bailey *et al.*, 1995). A more recent study of 34 Welsh boys and girls, aged between 8 and 10 years, set out to assess the relationships between data from a tri-axial accelerometer, a pedometer, and heart rate monitor (Rowlands *et al.*, 1999). The accelerometer and pedometer were worn for up to six days while heart rate was measured for one day. The average correlations between accelerometer and heart rate data were 0.63 and 0.60 for boys and girls, respectively, while the average correlations between accelerometer and pedometer data were 0.85 and 0.88 for boys and girls, respectively. Despite these findings, heart rate was not significantly associated with endurance time in a treadmill exercise challenge whereas the accelerometer and pedometer were more strongly associated with the treadmill testing. Consequently, the authors suggested that above a certain threshold, heart rate monitoring may be misleading as a measure of physical activity.

### 1.4.4 Age and Gender Differences in Physical Activity

Objective and some subjective monitoring consistently show boys participate in more physical activity than age-matched girls. Dublin boys as young as seven years regularly participated in more physical activity than girls of the same age, as assessed by questionnaire (Hussey *et al.*, 2001), while a study of 9- to 17-year old Irish children reported that boys exercised more than girls at all ages, even though both genders decreased their physical activity participation with age (The National Health and Lifestyle Surveys, 1999). In addition, a Canadian study of 220 boys and 246 girls in grades 5 to 8 found that boys were more physically active than girls, as assessed by the 7-day recall Physical Activity Questionnaire for Older Children (Crocker *et al.*, 2000). Moreover, a review of physical activity literature published in 1993 reported that there is a consistent decline in physical activity throughout the school age years, with males decreasing, on average, about 2.7% per year and females decreasing about 7.4% per year (Sallis, 1993). Much of this decline can be attributed to a decreased participation in non-organised sport (van Mechelen *et al.*, 2000; Trost *et al.*, 2002).

The accumulation of body fat through puberty, which is more pronounced in females (Malina *et al.*, 1988; Guo *et al.*, 1992) and likely to result in a greater energy expenditure for a given activity (Ekelund *et al.*, 2002), may also partly explain the difference in genders and the decrease in physical activity participation with age. Additionally, it has been suggested that throughout the school-age years, boys may have a preference for more vigorous activities such as rugby and soccer, which require greater energy expenditure on average than more female orientated activities such as ballet (Hussey *et al.*, 2001). This concept has been supported by reports that the gender difference in physical activity is greatly reduced when moderate activity alone is compared (Riddoch & Boreham, 1995; van Mechelen *et al.*, 2000; Trost *et al.*, 2002). Furthermore, investigations of social-cognitive determinants of activity behaviour could help to explain the gender difference in physical activity. Boys were observed to be more confident in their ability to overcome traditional barriers to physical activity including time constraints, feelings of fatigue, poor weather, and homework obligations (Trost *et al.*, 1996). Some other factors which have been put forward to explain the gender difference in physical activity include differences in motor skill development (Thomas & French, 1985) and differences in parental beliefs (Perusse *et al.*, 1989; Brustad, 1996). Moreover, several groups have also suggested that the socialization of the family unit exerts a significant influence on behaviours such as exercise (Herkowitz, 1980; Butcher, 1983; Stucky-Ropp & DiLorenzo, 1993; Trost *et al.*, 1996).

### 1.4.5 Physical Activity and Body Composition

If energy intake exceeds energy expenditure over time, there will be a storage of the excess energy, primarily as an accumulation of body fat. Overweight and obesity may be a result of a high energy intake, a low energy expenditure or, typically, a combination of both. Given that physical activity has the greatest potential for increasing a person's energy expenditure, it is not surprising that a low level of physical activity has been associated with childhood obesity. In fact, low levels of physical activity have been suggested as the key reason for the continued increase in the prevalence of overweight and obesity over recent decades (Magarey *et al.*, 2001; Yu *et al.*, 2002; Booth *et al.*, 2003). However, there is conflicting evidence regarding the association between physical activity and its impact on levels of overweight and obesity (Bar-Or & Baranowski, 1994; Ward & Evans, 1995).

In a review by Bar-Or and Baranowski (1994) which focused on physical activity in obese adolescents, only five studies out of 13 demonstrated a significant inverse relationship between physical activity and excess body mass. Bar-Or and Baranowski highlighted that one problem in assessing physical activity is that some authors approached physical activity as a behavioural phenomenon while others measured energy expenditure, the physiologic corollary of physical activity. Furthermore, when energy expenditure was reported, it was often presented in absolute energy units, therefore lacking any correction for the larger body mass of the obese individuals. Another possible confounding factor was the physical location of the study. For example, one study which observed obese boys to be substantially less active at home when compared to their non-obese siblings, found the obese boys to be equally active when in the playground (Waxman & Stunkard, 1980). Overall, Bar-Or and Baranowski (1994) highlighted that a major constraint in assessing the association between body composition and physical activity was the lack of standardised assessment of adiposity, physical activity and energy expenditure. They suggested the measurement shortcomings limit the possibility of providing a conclusive summary of generalisable findings. Subsequently, in studies in which physical activity was reduced in obese adolescents, the total energy expenditure of the obese may be equal or even higher than that of their leaner counterparts due to obese individuals having to carry a greater load (i.e. increased body mass for the same absolute work rate). This concept was further supported by Ekelund *et al.* (2002), who compared the physical activity of eight obese males and ten obese females (aged 14 to 19 years) against an age-matched control group. Results showed physical activity was not necessarily equivalent to the energy costs of activity.

A similar review by Ward and Evans (1995) on physical activity levels among obese youngsters also returned equivocal results. While some studies reported decreased physical activity levels among obese youth compared to age-matched controls, studies with the finding of no difference in physical activity level are similar in number. In their summary, Ward and Evans echoed many of the comments made by Bar-Or and Baranowski (1994), highlighting that the difficulties associated with defining and assessing physical activity plagued research in the area. Moreover, Ward and Evans recommended that obesity should be defined using standardised criteria and that the development of more appropriate instruments for the measurement of physical activity was imperative.

### 1.4.6 Physical Activity in Asthmatics and Non-Asthmatics

Several studies have suggested that children with asthma, particularly those with EIA, are not as physically active as non-asthmatic children (Croft & Lloyd, 1989; Thio *et al*., 1996; Santuz *et al*., 1997). Whether it is because asthma is likely to be precipitated by exercise or that asthmatic children have chronic airway obstruction, the suggestion is that the experience of exercise is not as rewarding for asthmatic as it is non-asthmatic children. Despite the speculation, only a limited number of studies have assessed the physical activity levels of asthmatics. Limited reports show differing conclusions when data from asthmatic children are compared to their non-asthmatic counterparts. The inherent difficulties associated with accurately recalling habitual levels of physical activity by questionnaire, particularly in children (Baranowski & Simons-Morton, 1991; Sallis *et al.*, 1996), may substantially affect the reliability of the measurement.

#### 1.4.6.1 Physical Activity Levels

Nystad *et al*. (1997) assessed physical activity levels in a paediatric cohort of asthmatic and non-asthmatic children by administering the International Study of Asthma and Allergies in Childhood (Asher *et al.*, 1995) questionnaire to 4021 school children in three areas of Norway. No differences were found between the exercise frequency in children who reported infrequent episodes of asthma or those with current asthma when compared to non-asthmatics. Also, there were no differences in the number of hours spent exercising per week between the groups (Nystad, 1997). In support, a study of Hong Kong Chinese children was unable to establish any association between physical inactivity and respiratory disease or symptoms, including asthma (Wong *et al.*, 2001). However, the authors suggested that the population studied may participate in low levels of physical activity overall, which may have contributed to the lack of a measurable difference.

Conversely, 65 asthmatic children were found to be more frequently active than 343 non-asthmatic children as measured by a self-administered questionnaire (Weston *et al.*, 1989). Although asthmatics were found to experience higher degrees of anxiety prior to exercise, they reported higher school and all-day physical activity levels. Similarly, in a study of over 16,000 Canadian children of at least 12 years age, asthmatics tended to have higher mean enegy expenditure values than non-asthmatics (Chen *et al.*, 2001).

In contrast, a recent study in which the parents of children aged 6 to 12 years (137 asthmatic; 106 non-asthmatic) were interviewed by telephone, asthmatic children were found to be less active than their peers. Moreover, an inverse association was found between asthma severity and physical activity level (Lang *et al.*, 2004). More recently, Firrincielli *et al.* (2005) also reported physical activity deficits among asthmatic children and adolescents. Fifty-four children aged 3-5 years wore Actiwatch® accelerometers over a 6- to 7-day period, and of the sample, 14.8% had wheeze in the previous 12 months whilst 7.5% had visited an emergency department within the previous 12 months for wheeze. It was found that physical activity levels were decreased among asthmatic children, with significant differences between measures of activity relating to prolonged or sustained physical activity. Moreover, the correlates of asthma that were associated with the decreased levels of physical activity included: 1) a history of wheezing in the previous 12 months; 2) a diagnosis of asthma, and 3) a presentation to the emergency department in the previous 12 months for wheezing or asthma. The authors concluded that a decreased physical activity could contribute to persistence of asthma or put children at a higher risk for obesity and other chronic diseases.

An adult study investigated the level of intensity of physical activity in 8000 Finnish participants with and without bronchial asthma (Mälkiä & Impivaara, 1998). Adult physical activity levels at work, during leisure time and whilst commuting were recorded using a questionnaire (Saltin & Grimby, 1968; Wilhelmsen *et al.*, 1971). Asthmatic men and women both recorded significantly lower levels of physical activity in each of the three time periods when compared to their non-asthmatic counterparts. In a study of U.S adults (Ford *et al.*, 2003), participants with current asthma had significantly lower energy expenditure than former asthmatics, who in turn had significantly lower energy expenditure than non-asthmatic respondents. Only 27% of the asthmatics were meeting the recommended physical activity requirements.

### 1.4.6.2 Physical Activity Summary

These data suggest that during childhood and adolescence, asthmatics may have physical activity levels comparable with those of the normal pediatric population. Nevertheless, the findings of Mälkiä and Impivaara (1998) and Ford *et al*. (2003) suggest that differences in asthmatic and non-asthmatic physical activity levels may develop during the time of maturation from adolescence into adulthood. However, published studies are limited by collectively inconsistent methodology, an absence of an asthmatic group and have failed to track the influence of asthma on physical activity over the range of early childhood into adulthood. The studies discussed in this section are summarised in Table 1.2.

**Table 1.2 Studies investigating asthma and physical activity in children, adolescents and adults**

| Study | Participants | Age (years) | Gender | Results | Method of PA Assessment |
|---|---|---|---|---|---|
| Wong *et al*., 2001 | 57 AS<br>1207 NAS | 8–12 | 43 M, 14 F<br>NR | No differences in PA between children with AS and/or bronchitis and NAS | Questionnaire |
| Nystad, 1997 | 4021 | 7–16 | 2030 M, 1991 F | Suggest AS have comparable PA levels to NAS | Questionnaire |
| Lang *et al*., 2004 | 137 AS<br>106 NAS | 6–12 | 79 M, 58 F<br>67 M, 39 F | AS less active than NAS | Telephone Interview |
| Firrincieli *et al*., 2005 | 12 AS, 42 NAS | 3–5 | 21 M, 33 F | AS significantly less prolonged and sustained PA | Accelerometer |
| Chen *et al*., 2001 | 1070 AS<br>15743 NAS | ≥12 | 410 M, 660 F<br>7090 M, 8653 F | AS had greater mean EE values than NA | Questionnaire |
| Weston *et al*., 1989 | 65 AS<br>343 NAS | 11–13 | NR | AS more frequently active than NAS | Questionnaire |
| Mälkiä & Impivaara, 1998 | 7193 | 30–89 | 3251 M, 3942 F | AS men and women recorded significantly lower PA questionnaire scores | Questionnaire |
| Ford *et al*., 2003 | 12 489 AS<br>4892 former AS<br>147 742 NAS | 18–70+ | 82 727 M<br>82 396 F | AS had lower PA levels than former AS and NAS | Telephone Interview |

AS = asthmatic children, F = females, M = males, NAS = non-asthmatic children, NR = not reported, PA = physical activity, EE = energy expenditure

## 1.5 Aerobic Fitness

### 1.5.1 Introduction and Definition

Aerobic fitness is as a functional index of the pulmonary, cardiovascular and haematologic components of oxygen delivery and the oxidative mechanisms of the exercising muscles (Armstrong *et al.*, 1999). Maximal oxygen consumption ($\dot{V}O_2$max) is the greatest oxygen uptake elicited during an exercise test to exhaustion and is well established as the most frequently cited indicator of cardiorespiratory fitness.

$\dot{V}O_2$max was originally described as the $\dot{V}O_2$ at which performance of increasing levels of constant work rate failed to increase $\dot{V}O_2$ by more than 150 ml/min, despite an increasing work rate (Taylor *et al.*, 1955). However, this definition has limitations as it is dependent on the exercise protocol and 150 ml/min may be too large a proportion of the greatest $\dot{V}O_2$ obtained in some patients (Wasserman *et al.*, 2005).

Maximal $\dot{V}O_2$ can also be determined by an incremental exercise challenge in which $\dot{V}O_2$ fails to increase normally in relation to the increase in work rate immediately prior to the subject fatiguing. However, in such incremental exercise tests, a plateau in the $\dot{V}O_2$-work rate relationship is not always observed. In this case, the greatest $\dot{V}O_2$ attained is referred to as the peak $\dot{V}O_2$ (Wasserman *et al.*, 2005).

For both children and adults, peak $\dot{V}O_2$ is often assessed by indirect calorimetry during incremental exercise testing on a cycle or treadmill ergometer. Such exercise testing offers the unique opportunity to study the cellular, cardiovascular and ventilatory systems' responses simultaneously under precise conditions of metabolic stress. Depending on its pathophysiology, a disease of the cardiovascular and/or ventilatory system affects the gas exchange pattern measured at the mouth and, as such, exercise testing provides a valuable insight into the underlying mechanisms.

Aside from attaining a measure of peak $\dot{V}O_2$, other parameters that can be attained from exercise testing include minute ventilation ($\dot{V}E$), volume of carbon dioxide production ($\dot{V}CO_2$), respiratory exchange ratio (RER; $\dot{V}CO_2/\dot{V}O_2$), heart rate response, anaerobic threshold, $\dot{V}O_2$/heart beat (or oxygen pulse), percentage of maximal voluntary ventilation (MVV) reached, dyspnoeic index ($\dot{V}E$/MVV), ventilatory equivalents for $O_2$ and $CO_2$, and end-tidal concentrations of $O_2$ and $CO_2$. These factors help to determine whether a ventilatory limitation to exercise is present as well as the presence of other abnormalities, including a shunt (i.e. blood flow to unventilated alveoli).

### 1.5.2 Aerobic Fitness and Health

Aerobic fitness not only determines performance in a wide range of activities, but is also a health-related parameter for children and adolescents. Children with a greater level of aerobic fitness were reported to have lower total cholesterol, low-density lipoprotein cholesterol and triglyceride levels, and higher high-density lipoprotein cholesterol levels than children with low levels of aerobic fitness (Hager *et al.*, 1995; Andersen *et al.*, 2006). Furthermore, it has been suggested that young children who increase their aerobic fitness reduce their rate of age-related increase in blood pressure (Shea *et al.*, 1994). In addition, improvements in aerobic fitness have been associated with less depression and a greater self-reported self-esteem in children (Crews *et al.*, 2004). Importantly, a number of studies have reported an inverse association between excess body mass and aerobic fitness in children and adolescents (Stewart & Goldberg, 1992; Craig *et al.*, 1996; Johnson *et al.*, 2000; Yu *et al.*, 2002).

Improved aerobic fitness levels have been associated with improvements in breathing reserve (MVV - $\dot{V}E$), oxygen pulse and heart rate reserve at peak exercise (Orenstein *et al.*, 1985; Ramazanoglu & Kraemer, 1985; Counil *et al.*, 2003), and reduced ventilation and heart rate at a given workload (Orenstein *et al.*, 1985; Varray *et al.*, 1991). Such cardiorespiratory and peripheral muscle adaptations may result in an asthmatic child having a greater physiological reserve with which to respond to a bout of asthma or EIA and may attenuate or eliminate the occurrence of an EIA episode.

Limited information is available to describe the effect of physical training on the pathophysiology of asthma in children. Only bronchial hyper-responsiveness has been investigated (Matsumoto *et al.*, 1999; Wardell & Isbister, 2000) and these studies that report histamine sensitivity showed no significant reductions in response to training. As such, the impact that training programs may have on the symptoms of asthma in children remains equivocal. Neder *et al.* (1999) stated, "The impact of training on the clinical management of the underlying bronchial asthma remains controversial, particularly in the most severe patients". Nevertheless, a recently published review of the effects of physical training on children and adolescents with asthma reported the majority of training studies demonstrated reduced asthma symptoms such as the number of hospitalisations, frequency of wheeze, doctor consultations and medication habits, all of which improved quality of life (Welsh *et al.*, 2005). The evidence strongly supports the notion that aerobic training does not adversely affect the asthmatic child in terms of the incidence or severity of EIA or asthma symptoms.

Evidently, it is more desirable for children and adolescents (both non-asthmatic and asthmatic) to possess a greater level of aerobic fitness. Given that childhood and adolescence have been described as critical periods for the development of lifestyle patterns which can determine disease risk in adulthood (Cunnane, 1993), children and adolescents should aim to achieve a level of aerobic fitness that affords the protective health benefits described above (Stewart & Goldberg, 1992; Shea *et al.*, 1994; Hager *et al.*, 1995; Craig *et al.*, 1996; Johnson *et al.*, 2000; Yu *et al.*, 2002).

### 1.5.3 Relationship between Aerobic Fitness and Physical Activity

Despite the amount of evidence linking aerobic fitness and physical activity to a number of health benefits in children and adolescents, the association between aerobic fitness and physical activity is poor. Although there is a strong association between aerobic fitness and physical activity in adults (Seals *et al.*, 1983; Gossard *et al.*, 1986; Blumenthal *et al.*, 1991; Garfinkel *et al.*, 1992), there is conflicting evidence concerning the relationship in children and adolescents. Whereas some authors have reported a high level of physical activity to be related to high peak $\dot{V}O_2$ in boys aged 7 to 17 years (Mirwald *et al.*, 1981), others have shown that young people with different levels of peak $\dot{V}O_2$ did not differ significantly in their daily physical activity levels (Andersen *et al.*, 1984). Furthermore, physical activity and aerobic fitness have been reported to be significantly related in 7 to 12 year-old boys (Al-Hazzaa & Sulaimen, 1993), but in boys aged 6 to 17 years, this relationship was not established (Janz *et al.*, 1992).

In fact, a review which focused on the relationship between physical activity and aerobic fitness among children and adolescents reported a balance of support both for and against the existence of such a relationship (Morrow & Freedson, 1994). In their review, Morrow and Freedson (1994) identified 37 “conclusions” in total. Seventeen of these conclusions suggested a positive relationship between physical activity and maximal oxygen consumption, whereas 20 conclusions suggested no relationship. Taken together, the median correlation was low, at $r = 0.17$ ($R^2 < 0.03$), which is likely to be a reflection of a clustered analysis. Importantly, all studies with a sample size of 186 or larger, detected a significant relationship between activity and fitness. Morrow and Freedson concluded that typical daily physical activity probably has a weak association with maximal oxygen consumption in youth and adolescents.

Despite the poor association between physical activity and aerobic fitness observed in the normal paediatric population, some authors suggest asthmatic youth may present a deficit in aerobic fitness (Strunk *et al.*, 1988; Varray *et al.*, 1989; Riedler *et al.*, 1994; Counil *et al.*, 2001; van Veldhoven *et al.*, 2001). If we consider the concept that asthmatic children and adolescents have a ventilatory limitation to exercise, then the existence of a positive relationship between aerobic fitness and physical activity in this population seems more probable. Specifically, if an initial deficit in aerobic fitness were present, increases in the level of physical activity may result in improvements in aerobic fitness, thereby creating a more discernable relationship.

### 1.5.4 Aerobic Fitness and Body Composition

The literature relating body composition to exercise performance capability in children and adolescents is contradictory. Whereas some authors have reported an inverse association between body fat and aerobic fitness in children and adolescents (Davies *et al.*, 1975; Nassis *et al.*, 2005), others suggest the aerobic fitness of overweight and obese children and adolescents is comparable to their non-obese counterparts (Elliot *et al.*, 1989; Maffeis *et al.*, 1994). When aerobic fitness is reported as ml.min$^{-1}$ per kilogram body weight, overweight and obese youth generally display lower values than their normal weight peers (Armstrong *et al.*, 1991; Rowland, 1991). However, when aerobic fitness is expressed in terms of FFM, some groups report the differences to disappear and that an excess body mass may not necessarily limit an individual's ability to maximally consume oxygen (Elliot *et al.*, 1989; Maffeis *et al.*, 1994).

### 1.5.5 Field Tests of Aerobic Fitness

A number of field based tests have been used to assess aerobic fitness. A 9-minute running test (Strunk *et al.*, 1988), the Maximal Multistage 20-meter Shuttle Run Test (Leger & Lambert, 1982), a 12-minute running test (Nickerson *et al.*, 1983) and the 6-minute running test (Silverman & Anderson, 1972; Kemp *et al.*, 2000; Roberts *et al.*, 2001) have been used as predictive methods for the estimation of $\dot{V}O_2max$ in asthmatic and non-asthmatic children.

### 1.5.5.1 Six-Minute Running Test – 6MRT

The six-minute running test (6MRT) was employed in a validation study by van Mechelen *et al.* (1986), who tested 41 boys and 41 girls aged 12-14 years, against a treadmill graded exercise test (GXT) performed to determine $\dot{V}O_2max$ by indirect calorimetry. The correlation coefficients between the two tests, $r = 0.51$ for boys and $r = 0.45$ for girls, were modest, but reached significance. Although van Mechelen *et al.* (1986) concluded the 6MRT was a valid measure of aerobic fitness, no results concerning the reliability of the 6MRT were reported and no equation was generated for predicting peak $\dot{V}O_2$ from the distance covered in the 6MRT. Kemp *et al.* (2000) tested the validity and reliability of the 6MRT among asthmatic and non-asthmatic boys and, subsequently, developed a predictive formula for estimating peak $\dot{V}O_2$ from the six-minute run distance (6MRD). A significant association was found between 6MRD and peak $\dot{V}O_2$ values from the GXT for the Grade 5 and 8 groups, with Pearson's r values of 0.44 and 0.54, respectively. Grade 5 boys ($n = 96$) and Grade 8 boys ($n = 131$) performed the 6MRT twice, displaying a high test-retest reliability with a correlation coefficient for the Grade 5 boys of 0.85 and the Grade 8 boys of 0.74. In a similar fashion, Roberts *et al.* (2001) tested the reliability and validity of the 6MRT in non-asthmatic school girls and also developed a predictive formula for estimating peak $\dot{V}O_2$ from 6MRD values. Pearson's correlation coefficients for Grade 5 and Grade 8 girls were 0.94 and 0.79, respectively, with no difference in the means between repeated running tests. A significant association between 6MRD and GXT peak $\dot{V}O_2$ values was also found, with Pearson's r values of 0.58 and 0.64 for Grade 5 and Grade 8 girls, respectively.

Despite its many advantages, the 6MRT does have several inherent limitations as a predictor of aerobic capacity. Children and adolescents completing the 6MRT are required to pace themselves throughout, a task which is often difficult for young people. In addition, performance in this test can be greatly affected by motivation and, given that the test is often performed outdoors, environmental conditions can also influence the outcome. However, the 6MRT is a valid and reliable method (van Mechelen *et al*., 1986; Kemp *et al*., 2000; Roberts *et al*., 2001) which can be used to assess aerobic capacity in large groups at minimal cost.

### 1.5.6 Normative Values of Peak $\dot{V}O_2$ for Children and Adolescents

Table 1.3 lists a selection of studies comprising primarily of untrained, non-asthmatic, Caucasian children in which peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$) values were determined by indirect calorimetry during a GXT on cycle, treadmill or rowing ergometers.

**Table 1.3 Normal peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$) values attained via indirect calorimetry in children and adolescents**

| Boys Peak $\dot{V}O_2$ (age) | Girls Peak $\dot{V}O_2$ (age) | N | Ergometer | Reference |
|---|---|---|---|---|
| 42.0 ± 6.0<br>(≤13.0 years)<br>50.0 ± 8.0<br>(>13.0 years) | 38.0 ± 7.0<br>(≤ 11.0 years)<br>34.0 ± 4.0<br>(> 11.0 years) | 58 M, 51 F | Cycle | (Cooper & Weiler-Ravell, 1984) |
| 53.2 ± 5.4<br>(12-14 years) | 44.1 ± 4.8<br>(12-14 years) | 41 M, 41 F | Treadmill | (van Mechelen *et al.*, 1986) |
| 51.0 ± 6.0<br>(11.1 years) | 45.0 ± 5.0<br>(10.9 years) | 111 M, 53 F | Treadmill | (Armstrong *et al.*, 1995) |
| 52.0 ± 6.0<br>(12.2 years) | 44.0 ± 5.0<br>(12.2 years) | 93 M, 83 F | Treadmill | (Armstrong *et al.*, 1998) |
| 49.3 ± 7.1<br>(11.2 ) | 42.7 ± 7.3<br>(11.2) | 119 M, 115 F | Treadmill | (Armstrong *et al.*, 1999) |
| 46.1 ± 5.8<br>(10.9-12.8 years) | 43.1 ± 5.6<br>(10.9-12.8 years) | 13 M, 24 F | Treadmill | (Rowland & Boyajian, 1995) |
|  | 40.0 (11.7 years) | 24 F | Cycle | (Rowland *et al.*, 2000) |
| 42.9 ± 7.9<br>(9 – 12 years) |  | 16 M | Rowing | (Gibson *et al.*, 2000) |

Mean ± SD
M = Male, F = Female

### 1.5.7 Age and Gender Differences in Peak $\dot{V}O_2$

It is well established that boys have greater peak $\dot{V}O_2$ values than girls of the same age throughout childhood and adolescence, with several cross-sectional studies reporting significant differences (Armstrong *et al.*, 1991; Armstrong *et al.*, 1995; Armstrong *et al.*, 1999). A review of the aerobic power literature reported that aerobic power relative to body mass remains stable among males between the ages of 6 to 16 years, but for females aerobic power declines at around 2% per annum (Sallis, 1993). Overall, males are about 25% more aerobically fit than females (Sallis, 1993). In agreement, another review which focused on the relationship between peak $\dot{V}O_2$ and chronological age reported that from the age of 10 years, male peak $\dot{V}O_2$ values are greater than those of females (Armstrong & Welsman, 1994). In 1996, a comment on the interpretation of aerobic fitness in youth reported that a remarkably consistent level of mass-related peak $\dot{V}O_2$ is observed in boys over the adolescent period with typical values of 49.0–50.0 $ml.kg^{-1}.min^{-1}$, while, in contrast, there is a marked tendency for mass-related peak $\dot{V}O_2$ in adolescent females to decline from 45.0 to 39.0 $ml.kg^{-1}.min^{-1}$ through adolescence (Åstrand, 1952; Åstrand, 1956; Daniels & Oldridge, 1971; Cunningham *et al.*, 1984; Cunningham *et al.*, 1984).

Through puberty, marked increases in haemoglobin concentration are observed in boys, and hence an increase in the oxygen-carrying capacity is reported in boys. However haemoglobin concentrations tend to remain unchanged in females (Kemper & Verschuur, 1981). It is therefore expected that the differences in haemoglobin levels between boys and girls would at least partially contribute to the observed gender difference in peak $\dot{V}O_2$, a concept which has been demonstrated in 14- and 15-year olds (Armstrong *et al.*, 1991). In addition, the gender difference in peak $\dot{V}O_2$ has been attributed to the greater accumulation of body fat in relation to body mass in girls (Malina *et al.*, 1988; Guo *et al.*, 1992), the greater muscle mass in boys than girls (Malina *et al.*, 2004) and the lower levels of habitual physical activity among girls than boys (Krahenbuhl *et al.*, 1985). However, the evidence relating habitual physical activity to peak $\dot{V}O_2$ is still equivocal (Morrow & Freedson, 1994; Boreham *et al.*, 1997; Katzmarzyk *et al.*, 1998; Rowlands *et al.*, 1999; Ekelund *et al.*, 2001; Dencker *et al.*, 2006).

### 1.5.8 Aerobic Fitness in Asthmatics and Non-Asthmatics

As outlined in Section 1.5.2, a superior level of aerobic fitness may be protective against an asthmatic episode. However, a common perception is that asthmatics may have a reduced capacity for exercise. Certainly, the degree of resting airway obstruction in asthmatic youth may significantly influence the ventilatory limitation to exercise (Babb *et al.*, 1991), while the degree of bronchial hyper-responsiveness may also limit exercise tolerance (Fairshter *et al.*, 1989; Anderson, 1993). However conflicting evidence exists in the literature in relation to the exercise capabilities of asthmatics (see review by Welsh *et al*. (2004)). Claims that asthmatics are not as aerobically fit as non-asthmatics are counteracted by other studies showing little or no difference in the fitness levels between asthmatic and non-asthmatic children and adolescents.

### 1.5.8.1 Comparable Aerobic Fitness between Asthmatic and Non-Asthmatic Children

Bevegård *et al*. (1971) assessed the $\dot{V}O_2$max of 20 mild to severely asthmatic boys on a cycle ergometer and concluded that "even children with severe asthma have a normal maximal oxygen uptake capacity". Similarly, Hedlin *et al*. (1986) evaluated the working capacity of 16 children with a history of EIA on an electrically-braked bicycle ergometer and found comparable peak $\dot{V}O_2$ values in EIA and non-asthmatic boys of the same age. Moreover, Fink *et al*. (1993) reported no differences in $\dot{V}O_2$max between groups of stable asthmatic and non-asthmatic children stratified into active and inactive groups. They concluded that a sedentary lifestyle was the probable cause for children to have poor aerobic fitness independently of an asthmatic condition, and that aerobic fitness had the potential to be normalised by training. Thio *et al*. (1996) also found 22 from a cohort of 28 mild to moderately severe asthmatic children to possess comparable $\dot{V}O_2$max values with the predicted values of non-asthmatic Dutch children of the same age, whilst Boas *et al*. (1998) found 22 asthmatic children and adolescents to produce similar values of $\dot{V}O_2$max to 22 age-matched non-asthmatic controls. Santuz *et al*. (1997) reported no difference in aerobic fitness between 80 mild to moderately severe asthmatic and 80 non-asthmatic children, as measured by a maximal treadmill exercise test. The study participants were matched for physical activity by their score on the Habitual Level of Physical Activity Questionnaire (Santuz *et al*., 1995). Matches were also made for age, height and weight. The authors concluded that, as long as physical activity levels are comparable to that of non-asthmatic children, asthmatics are capable of achieving a similar level of aerobic fitness.

### 1.5.8.2 Differences in Aerobic Fitness between Asthmatic and Non-Asthmatic Children

In contrast to the findings above, a number of investigations have demonstrated reduced aerobic fitness in asthmatic children when compared to non-asthmatic children. Strunk *et al*. (1988) examined the exercise performance of 76 asthmatic children via a 9-minute run and reported 91% of asthmatics performed below the $50^{th}$ percentile. The results indicated an extreme deficit in aerobic fitness. Varray *et al*. (1989) found 11 asthmatic children had significantly lower $\dot{V}O_2max$ values when compared with 11 non-asthmatic children who completed a maximal incremental exercise test on a cycle ergometer and were matched for age (11-13 years), gender, height and weight. In a study measuring fitness by a one-mile run in 16-year old high school football players, a difference of approximately 10% was reported between EIA affected and unaffected students (Kukafka *et al*., 1998). The 19 asthmatic adolescents recorded an average time of 513 seconds for the one-mile run compared with 466 seconds achieved by 214 non-asthmatic students. Unfortunately, 24 previously diagnosed asthmatics in this study did not complete the run. Riedler *et al*. (1994) was also able to demonstrate a difference of approximately 10% when randomly selected non-asthmatic children ran an average distance of 1131 metres in six minutes compared with 1035 metres by 70 asthmatics who demonstrated EIA. In these two field studies (Riedler *et al*., 1994; Kukafka *et al*., 1998), participants were not pre-medicated with preventative drugs. Another difference of around 10% in aerobic fitness was demonstrated by Counil *et al*. (2001) when comparing the cycle ergometer $\dot{V}O_2max$ values of 19 asthmatic boys to that of 14 non-asthmatic age-matched boys. In a training study on Dutch children, the 'most' asthmatic individuals (precise details not provided) from a cohort of 47 performed around or below the

10th percentile for $\dot{V}O_2max$ at pre-training assessment, as measured on a cycle ergometer (van Veldhoven *et al.*, 2001). In a large epidemiological study of aerobic fitness in Hong Kong Chinese children (Wong *et al.*, 2001), the predicted $\dot{V}O_2max$ measured via the Maximal Multistage 20-meter Shuttle Run Test, was significantly reduced in children with either asthma or bronchitis, compared to children without potentially limiting respiratory conditions. However, the children with only asthma were not separated from those with bronchitis in the analysis, so results are difficult to interpret. Table 1.4 summarizes the studies focusing on aerobic and anaerobic fitness in children and adolescents with asthma.

**Table 1.4 Studies investigating asthma, aerobic and anaerobic fitness in children and adolescents**

| Reference | Participants | Age (y) | Gender | Results |
|---|---|---|---|---|
| (Bevegård *et al.*, 1971) | 20 AS | 8 – 13 | 20 M | Normal $\dot{V}O_2max$ |
| (Boas *et al.*, 1998) | 22 AS<br>22 NAS | 7 – 18 | 22 M<br>22 M | No difference in $\dot{V}O_2max$ between the AS and NAS.<br>No difference in anaerobic fitness |
| (Counil *et al.*, 2001) | 19 AS<br>14 NAS | 11.5 – 15.7 | 19 M<br>14 M | AS had 10% lower $\dot{V}O_2max$ and lower maximal anaerobic power |
| (Fink *et al.*, 1993) | 49 AS<br>31 NAS | 9 – 16 | 27 M, 22 F<br>NR | All active AS had comparable aerobic fitness to NAS |
| (Hedlin *et al.*, 1986) | 16 AS<br>9 NAS | 10.1 – 14.3 | 10 M, 6 F<br>9 M | No difference in $\dot{V}O_2max$ between AS and NAS |
| (Kukafka *et al.*, 1998) | 19 AS<br>195 NAS | 14 – 18 | 214 M | AS took 10% longer to complete mile run |
| (Riedler *et al.*, 1994) | 152 AS<br>70 AS | 13 – 15 | NR | NAS ran 10% further than AS in 6 minute run |
| (Santuz *et al.*, 1997) | 80 AS<br>80 NAS | 7 – 15 | 60 M, 20 F<br>NR | No difference in aerobic fitness |
| (Strunk *et al.*, 1988) | 76 AS | 9 – 17 | 42 M, 34 F | 91% of AS performed below the $50^{th}$ percentile in a 9 minute run |
| (Thio *et al.*, 1996) | 28 AS | 6 – 13 | 17 M, 11 F | 22 children had normal $\dot{V}O_2max$. Six children performed below the $5^{th}$ percentile |
| (van Veldhoven *et al.*, 2001) | 47 AS | 8 - 13 | 34 M, 13 F | Most AS children performed around or below the $10^{th}$ percentile for $\dot{V}O_2max$ |
| (Varray *et al.*, 1989) | 11 AS<br>11 NAS | 11 – 13 | 9 M, 2 F<br>9 M, 2 F | AS recorded lower $\dot{V}O_2max$ values compared with the NAS |
| (Wong *et al.*, 2001) | 57 AS<br>1207 NAS | 8 – 12 | 43 M, 14 F<br>NR | Reduced $\dot{V}O_2max$ in children with asthma and/or bronchitis |

AS = asthmatic children, F = females, M = males, NAS = non-asthmatic children, NR = not reported, $\dot{V}O_2$ max = maximal oxygen consumption

### 1.5.8.3 Aerobic Fitness Summary

Forty-seven studies were located that focused on fitness in asthmatic children and adolescents. However, only 13 of these studies reported baseline (untrained) aerobic fitness in asthmatic young people (Table 1.4). Anomalies among these investigations included either a comparison of aerobic fitness with a control group of non-asthmatic children, or a comparison with established percentile scales. Studies were included in Table 1.4 regardless of the method used to estimate aerobic fitness and publication length was not an exclusion criteria. Specifically, articles published as abstracts, short reports or otherwise were not excluded.

Seven studies are identified above in which aerobic performance is significantly lower in asthmatic children compared with non-asthmatics; however, six studies have also been described in which no difference could be established. Therefore, no consensus to date has been established on differences that may exist between the cardiorespiratory health of asthmatic youth and their non-asthmatic counterparts. There are three main areas that have contributed to this problem, namely sample selection, methodological variations and statistical analysis. Most studies in which fitness is measured using indirect calorimetry used relatively small sample sizes (Bevegård *et al.*, 1971; Hedlin *et al.*, 1986; Varray *et al.*, 1989; Thio *et al.*, 1996; Boas *et al.*, 1998; Counil *et al.*, 2001). Conversely, studies with larger participant numbers (generally field studies) do not always compensate for the increased variability of the sample (Fink *et al.*, 1993; Santuz *et al.*, 1997). Often non-asthmatic control groups have not been randomly selected and the gender and age distribution in these groups are not reflected in the asthmatic test group (Bevegård *et al.*, 1971; Hedlin *et al.*, 1986;

Strunk *et al.*, 1988; Fink *et al.*, 1993; Kukafka *et al.*, 1998). Furthermore, few studies incorporate the full range of asthma severity in a single study (Bevegård *et al.*, 1971). Particularly important is the need to assess fitness in more severe patients to compare asthmatics at the trivial to mild end of the severity spectrum (Bevegård *et al.*, 1971). Methodological difficulties arise from estimating aerobic fitness from field tests (Strunk *et al.*, 1988; Riedler *et al.*, 1994; Kukafka *et al.*, 1998) when results are compared with measurements of peak $\dot{V}O_2$ via indirect calorimetry. Anecdotal information suggests that testing asthmatic children with and without pre-medication affects peak $\dot{V}O_2$ scores; however, to our knowledge, no study addresses this issue. Finally, a number of studies have used inappropriate statistical analyses, thereby limiting the validity of the conclusions (Hedlin *et al.*, 1986; Wong *et al.*, 2001). These deficiencies in the literature highlight the need for more research.

### 1.5.8.4 Interaction between Aerobic Fitness, Physical Activity, Asthma and Adiposity

Although several studies have focussed on physical activity levels and aerobic fitness in the asthmatic population, a paucity of evidence supports the presence of an interaction between physical activity, aerobic fitness and paediatric asthma. Some studies measuring aerobic fitness in asthmatics and non-asthmatic control groups, matched their recruits for physical activity, thereby preventing an evaluation of whether a relationship exists between asthma, physical activity and aerobic fitness. Results of these studies have been equivocal, with some showing reduced fitness (Varray *et al.*, 1989; Kukafka *et al.*, 1998) and others no difference in aerobic performance (Santuz *et al.*, 1997; Counil *et al.*, 2001).

Fink *et al*. (1993) is one of only two studies to include measurements of physical activity and aerobic fitness in asthmatics and non-asthmatics without matching either variable. Following recruitment, asthmatics were divided into three categories – sedentary, inactive and active. Sedentary subjects did not participate in organized sports and avoided free-play, while the inactive group participated in regular gymnastic activities at school and free-play only at home. The active group participated in organized and competitive sports at least three times per week for durations of no less than 60 minutes per session. The control group consisted of only inactive and active participants. No significant differences were found between the exercise performances of asthmatics and non-asthmatics within each category; however, the sedentary asthmatics had significantly lower aerobic fitness compared with the inactive asthmatic and control groups, suggesting a possible dose-related effect. Interestingly, Wong *et al*. (2001) reported children with either asthma or bronchitis had lower $\dot{V}O_{2max}$ values compared with non-asthmatics of the same age. They reported a significant relationship between $\dot{V}O_2max$ and physical activity, but could not confirm an association between physical activity and respiratory disease or symptoms.

One factor influencing the relationship between aerobic fitness, physical activity and asthma may be an intuitive link between asthma and obesity in children (Tantisira & Weiss, 2001; Ford, 2005; Shore & Johnston, 2006) – see Section 1.3.8. Immune modification together with the genetic, mechanical and sex-specific effects of obesity are collectively believed to contribute to the association. For comprehensive review of this association, see reviews by Tantisira & Weiss (2001), Shore & Johnston (2006) or Ford (2005). However, environmental factors such as diet and physical activity are also thought to contribute to the association

(Black & Sharpe, 1997; Epstein *et al.*, 2000; Platts-Mills *et al.*, 2000). Gilliland *et al*. (2003) examined 3792 school-age children to determine if an interaction existed between obesity and new-onset asthma. The relative risk of a new diagnosis of asthma increased in the upper BMI percentiles for both boys and girls. The authors concluded that being overweight significantly increased the relative risk of developing new-onset asthma in boys and non-allergic children.

#### 1.5.8.5 Aerobic Fitness, Physical Activity and Asthma Summary

Overall, the data addressing whether asthmatic children have different levels of aerobic fitness compared to their non-asthmatic counterparts is inconclusive. Methodological differences have likely contributed to the lack of agreement across studies – this only highlights the need for further research to better elucidate the relationship, particularly with larger sample numbers and investigations including the full spectrum of asthma severity.

Most of the limited published data suggest physical activity levels of asthmatic children and adolescents are similar with non-asthmatic children and adolescents. While differences reported for adults suggest a greater decrease in physical activity for asthmatics with maturity, the lack of objectively measured data and the need to account for asthma severity make it impossible to adequately assess whether differences in habitual physical activity exist between asthmatic and non-asthmatic children. Further work using normative and somewhat large population studies is clearly required.

## 1.6 Aims of this Thesis

As highlighted in this Introduction, the literature regarding the relationship between physical activity and aerobic fitness among children and adolescents lacks consistency. However, this may chiefly be due to methodological inadequacies. Similarly, there is conflicting evidence relating physical activity to overweight and obesity in children and adolescents, and disagreement in relation to the association between aerobic fitness and an excess body mass. In addition, overweight/obesity and asthma prevalence have risen dramatically in recent decades and the proposal of an asthma-obesity association may also influence the interactions between activity, fitness and body composition in children with asthma. Furthermore, the concept of asthmatic youth having a reduced capacity for exercise also remains largely unconfirmed. Given the younger years are likely to be a critical period for the determination of future health, a better description of the relationships between daily physical activity, fitness, body composition, asthma status and asthma severity in youth is needed. In this context, the specific aims of this thesis were as follows:

**Aim 1:** To describe normative body composition data for school children and adolescents, between the ages of 10 and 14 years, in order to advance knowledge of current secular trends of overweight and obesity. As part of this purpose, it was aimed to compare the measurement variance associated with different field-based techniques of body fat determination specific to the population in question.

**Aim 2:** To establish normative physical activity and aerobic fitness data in non-asthmatic youth in order to determine the interactions between these variables and body composition, taking into account the influence of age and gender upon these variables.

**Aim 3:** To determine whether a relationship exists between asthma and the prevalence of overweight and obesity.

**Aim 4:** To determine the relationship that asthma, as well as the severity of the condition, has with physical activity and aerobic fitness in children and adolescents, and to ascertain whether a ventilatory limitation to exercise and/or an altered physical activity participation is present in asthmatic youth.

**Aim 5:** To determine whether severely asthmatic youth (under-represented in the literature) display levels of physical activity and aerobic fitness similar to less-severe asthmatics and/or non-asthmatics of the same age.

# Chapter 2 General Methodology

The data in the following chapters was collected in two locations:

(a) Field-based data were gathered from children and adolescents in the school environment (Chapters 3-4). Throughout this thesis, these participants may be referred to as 'school tested'.

(b) Laboratory-based data were collected from children and adolescents who visited the Respiratory Laboratory at the Royal Children's Hospital, Melbourne (Chapter 5). These participants may be referred to as 'laboratory tested' at times in this thesis.

## 2.1 School Tested Participants

This cross-sectional study was conducted at 21 government and independent schools in the Melbourne metropolitan area between 2001 and 2004, with approval from the Royal Children's Hospital and Australian Catholic University Ethics in Human Research Committees (Appendix I). Schools were approached individually, and upon receiving approval, parents and guardians of all grade 5 and grade 8 students (age range 10 to 14 years) were sent a detailed information brochure inviting their child to participate in the study. This brochure included a standard consent form (Appendix B) and a copy of the ASQ (Rosier *et al.*, 1994) (Appendix C). Asthma status (non-asthmatic/asthmatic) was determined by parental response to the ASQ. Specifically, children who were currently taking anti-asthma medication were deemed to be asthmatic, while all others were classified as non-asthmatic. Asthma severity (trivial, mild, moderate, severe) was also determined by scoring the parental response to the ASQ (Rosier *et al.*, 1994).

## 2.2 School Tested Procedure

### 2.2.1 Height and Weight Measurement

A three-person team tested 635 participants in groups of six to eight over a period of approximately 60 minutes. Firstly, height was recorded to the nearest 0.1 cm without shoes using a portable stadiometer (Seca Model 214, Hamburg, Germany). Weight was then measured in minimal clothing, again without shoes, to the nearest 0.1 kg using digital scales (Tanita BWB 600, Tanita Corporation, Tokyo). The standard equation (weight(kg)/height$^2$(m)) was employed to calculate BMI.

### 2.2.2 Skinfold Measurement and Bioelectrical Impedance Analysis

Following height and weight measurement, skinfold measurements and bioelectrical impedance analysis were performed. Harpenden skinfold calipers (British Indicators Ltd, St Albans, Hertfordshire) were used to measure skinfold thicknesses at the biceps, triceps, subscapular and suprailiac sites as specified by (Durnin & Rahaman, 1967). The biceps measurement was made over the mid-point of the muscle belly (i.e. between the anterior auxiliary fold and the antecubital fossa) while the participant’s forearm rested in the supinated position on their thigh. The triceps measurement was made with a vertical fold on the posterior midline of the upper arm, halfway between the acromion process and olecranon process while the upper arm was hanging vertically and relaxed (Edwards *et al.*, 1955). The subscapular measurement was taken between 1 to 2 cm from the inferior angle of the scapula, at an angle of around 45º. The suprailiac measurement was taken as a diagonal fold slightly above the iliac crest at the spot where an imaginary line would come down from the anterior auxiliary line just above the hip bone and 2 to 3 cm forward. To ensure consistency, one experienced operator performed all of the skinfold measurements, always measuring on the right side of the body. The standard error of the estimate for skinfold measurements equated to 2.3 %BF. Furthermore, measurements were only taken on healthy undamaged, uninfected dry skin.

Participants were instructed to relax their muscles during testing. The skinfold was firmly grasped by the thumb and index finger of the operator, using the pads at the tip of the thumb and finger to gently pull the skinfold away from the body. The caliper was placed on the fold at approximately 1 cm below the finger and thumb. While the operator maintained grasp of the skinfold, the caliper was released to exert full tension on the skinfold for one to two seconds after the grip was fully released. A minimum of two measurements were recorded at each site to the nearest 0.5 mm. The values presented in this thesis are the mean of the two measurements deemed to best represent the skinfold site. The equations of Siri *et al.* (1956) and Durnin and Rahaman (1967) were combined to calculate %BF (see Section 2.2.2.1).

Bioelectrical impedance analysis was performed using a Biodynamics® Model 310e single-frequency (50 kHz) body composition analyser (Biodynamics Corporation, Seattle, Washington) – see Figure 2.1 (Appendix K: Chapter 2 Appendices). All measurements were carried out using the same device. Prior to analysis, the participant's height, weight, gender and age were entered into the analyser. After removing the right shoe and sock, participants were instructed to lie in the supine position on a non-conducting surface with their feet at least 15 cm apart and their hands at least 15 cm from their sides. In accordance with the validated and most commonly used tetrapolar method (Lukaski *et al.*, 1986), two disposable electrodes were placed on the dorsal surface of the participant's right hand between the distal prominences of the radius and ulna and another two disposable electrodes were placed on the dorsal surface of the uncovered right foot between the medial and lateral malleoli – see Figure 2.2. Sensor cables were attached to the electrodes, completing the circuit to the analyser. Participants were instructed to lie still while a harmless, imperceptible low-level alternating current (<1 mA, 50 kHz) was passed through their body over a few seconds. The analyser provided values of bio-resistance and % BF.

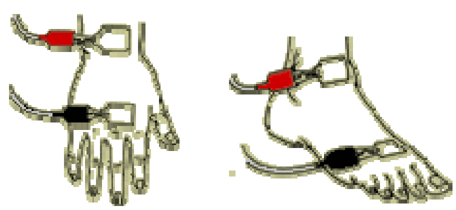


**Figure 2.2 Bioelectrical impedance analysis electrode placement**

In accordance with the validate tetraploar method (Lukaski *et al.*, 1986), two disposable electrodes were placed on the dorsal surface of the participant's right hand between the distal prominences of the radius and ulna and another two disposable electrodes were placed on the dorsal surface of the uncovered right foot between the medial and lateral malleoli. Source: www.biodyncorp.com

During preliminary statistical analysis, it became apparent that estimates of %BF derived from the sum of skinfolds and BIA methods may be significantly different. Consequently, an investigation into the variability between these two body composition estimation methods was conducted. A detailed analysis of the investigation is provided in Appendix A. In summary, Bland-Altman analysis revealed unacceptably wide limits of agreement, and BIA demonstrated the greater variability in the estimation of %BF among the participants from this study. Furthermore, estimates of %BF from BIA were significantly different from those derived by sum of skinfolds within each grade and gender group. As such, only the values derived from the sum of skinfold measurements were used when expressing %BF in chapters 3 and 4.

### 2.2.2.1 Percentage Body Fat Equations

Percentage body fat (%BF) as estimated from the sum of skinfolds was calculated using the equations of Siri (1956) and Durnin and Rahaman (1967).

The regression equations for the prediction of body density (Y) from the log of the sum of skinfold thicknesses at all four sites in mm (X) are as follows:

Males: $Y = 1.1533 - 0.0643\ X$ (Durnin & Rahaman, 1967)

Females: $Y = 1.1369 - 0.0598\ X$ (Durnin & Rahaman, 1967)

%BF = [4.95/body density – 4.5] x 100 (Siri, 1956).

Fat free mass (FFM) was calculated using the %BF values estimated from the sum of skinfolds. Specifically, FFM (kg) = Body Mass (kg) – (Body Mass (kg) x %BF derived from the sum of skinfolds).

### 2.2.3 Spirometry

To ensure that participants were eligible to complete the 6MRT, all children performed spirometry using a portable hand-held Jaeger Masterscope® spirometer connected to a Toshiba® notebook computer running Masterlab® software version 4.35 (Jaeger, Würzburg, Germany). Figure 2.3 shows an example of the Jaeger Masterscope® and Figure 2.4 shows the spirometry manoeuvre being performed. The spirometer was calibrated daily using a Hans Rudolph 3-litre syringe (Hans Rudolph Inc, Kansas City, Missouri, USA).

At least 10 minutes prior to performing spirometry, a member of the research team administered asthmatic children with a bronchodilator - 800μg of Ventolin™ (Salbutamol) via a Volumatic™ spacer and metered dose inhaler (Allen & Hanburys, Uxbridge, United Kingdom) according to a standardised protocol. This procedure was carried out to avoid or limit exercise-induced bronchoconstriction, providing asthmatic participants with the opportunity to perform to maximal effort during the exercise test to follow (i.e. 6MRT).

Participants were standing and wearing a nose clip when they performed the lung function manoeuvre. Firstly, the operator explained the spirometry test and demonstrated the appropriate technique. Participants were then instructed to place their lips around the disposable cardboard mouthpiece, and following one or two preliminary breaths, to inhale as deeply as possible and then to exhale maximally until no more air could be expelled, while maintaining an upright posture. Forced expiratory testing was conducted to obtain values for $FEV_1$ and FVC and was carried out according to American Thoracic Society criteria (American Thoracic Society, 1995). The testing was repeated six to eight times until at least two readings of $FEV_1$ were achieved that agreed to within 150 ml (American Thoracic Society, 1995). To be eligible to take part in the 6MRT, $FEV_1$ of participants was required to be equal to or greater than 75% of predicted normal values (Anderson, 1993).

**Figure 2.3 Jaeger Masterscope® spirometer fitted with elbow piece and disposable mouthpiece**

The spirometer consists of a heated pneumotachograph including a pressure sensor. The handle in shot is connected to a portable notebook computer for the measurement, evaluation and storage of spirometric indices, including FVC and $FEV_1$. The Masterscope® has a flow range of 0 - 20 litres per second and a volume range of 0 - 20 litres per second with a volume resolution of < 1 ml.

**Figure 2.4 Spirometry manoeuvre being performed by a grade 5 male (approximately 10 years old)**

Note that the participant is in an upright position, the noseclip is well tolerated and there is a tight seal around the disposable mouthpiece. The participant is watching a notebook monitor (off left of picture) for visual feedback. Spirometry was repeated six to eight times until at least two readings of $FEV_1$ were achieved that agreed to within 150 ml (American Thoracic Society, 1995). Asthmatic participants were medicated with a bronchodilator at least ten minutes prior to performing spirometry.

### 2.2.4 Six-Minute Running Test – 6MRT

Prior to beginning the 6MRT, participants were fitted with a Polar® Vantage NV heart rate monitor (Polar Electro Oy, Kempele, Finland). The electrodes on the transmitting belt were moistened with water before being fitted firmly around a participant's chest to improve signal transmission. The heart rate monitors were programmed to record heart rate every minute to assess whether, in the final 2-3 minutes of the 6MRT, participants achieved heart rates greater than 85% of their predicted maximal heart rate (West *et al.*, 1996), which was calculated using the equation, 210 – (0.65 x age) (Jones & Campbell, 1982).

For the 6MRT, participants were instructed to pace themselves, yet were also informed that the 6MRT was a race and that they should aim to run as far as possible. Verbal encouragement was constantly provided by investigators throughout the 6MRT. Participants ran in a counter-clockwise direction around either a flat-grassed oval or an outdoor hardcourt. A 100-m circular track was constructed using plastic cones spaced 10 metres apart. The distance run in six minutes (6MRD) was measured to the nearest 10-metre plastic cone. The 6MRT was performed in various seasons, though always in dry conditions. Figure 2.5 displays a selection of photographs with participants performing the 6MRT.

**Figure 2.5 Children and adolescents performing the six-minute running test (6MRT).** Participants ran in a counter-clockwise direction on either a flat-grassed oval or an outdoor hardcourt. A 100-m circular track was constructed using plastic cones spaced 10 metres apart. The distance run in six minutes (6MRD) was measured to the nearest 10-metre plastic cone. Participants were tested in groups of six to eight to encourage competitiveness. Verbal encouragement was continually provided by researchers throughout the 6MRT.

### 2.2.4.1 Six-Minute Running Distance (6MRD) to Predicted Peak $\dot{V}O_2$

The six-minute running distance (6MRD) was used to estimate peak $\dot{V}O_2$ by employing the equations originally developed by Kemp *et al*. (2000) and Roberts *et al*. (2001) – see Appendix D. The equations used are shown below.

**Grade 5 Males**

Predicted Peak $\dot{V}O_2$ (ml.kg$^{-1}$.min$^{-1}$) = (0.0332147 x 6MRD) + 10.58221

**Grade 5 Females**

Predicted Peak $\dot{V}O_2$ (ml.kg$^{-1}$.min$^{-1}$) = 1.062682 + (0.0332147 x 6MRD) + 10.58221

**Grade 8 Males**

Predicted Peak $\dot{V}O_2$ (ml.kg$^{-1}$.min$^{-1}$) = -3.14857 + (0.0332147 x 6MRD) + 10.58221

**Grade 8 Females**

Predicted Peak $\dot{V}O_2$ (ml.kg$^{-1}$.min$^{-1}$) = -3.14857 + 1.062682 + (0.0332147 x 6MRD) + 10.58221

### 2.2.5 Physical Activity Assessment

#### 2.2.5.1 Physical Activity Questionnaire for Children

Following the aforementioned data collection, responses to the PAQ-C (Crocker *et al.*, 1997) were gathered. Firstly, the operator explained how to correctly complete the PAQ-C. Participants were seated at a distance apart respectful of privacy and original answers were encouraged. Assistance was provided upon request, with care taken not to coach or influence a participant's response. The PAQ-C was conducted in silence and without time restriction. If a mistake was made, participants were instructed to make a clear distinction of their desired response. A copy of the PAQ-C is provided in Appendix E.

#### 2.2.5.2 Accelerometry – Activity Monitor

For participants providing consent and for which resources allowed, a sub-sample of participants were fitted with a preset ActiGraph 7164 accelerometer prior to departing the testing session. The ActiGraph 7164 is 51 x 41 x 15 mm in size and weighs 43 grams with a watch battery. The standard ActiGraph 7164 has 64 kilobyte of random access memory and can store up to 22 days worth of data. The ActiGraph 7164 has a dynamic range of 0.05 to 2.0 G, with a frequency response ranging from 0.25 to 2.5 Hz. These parameters confine measurements to human motion (Freedson *et al.*, 2005). Filtered acceleration signals are digitized by the ActiGraph 7164 and the magnitude is subsequently summed over a user-specified epoch. For the current study, a 60-second epoch was selected. For the purpose of this thesis, the ActiGraph 7164 accelerometer will be referred to as an activity monitor. The activity monitor was positioned firmly on the right hip using an elastic waist belt in accordance with the manufacturer's recommendations (ActiGraph, LLC, Fort Walton, Florida). Participants were then given verbal instructions about the correct use and care of the activity monitor, as well as a printed list of instructions to take home for reference (Appendix F). Participants were asked to wear the monitor during waking hours for seven consecutive days. Specifically, participants were instructed to fit the activity monitor into position at their first convenience when dressing in the morning and remove the activity monitor immediately prior to sleeping. Participants were also required to refrain from wearing the activity monitor during water-related activities (i.e. bathing or swimming). One or two days prior to activity monitor collection, the participant's school was contacted by telephone to remind them of the date and time that the activity monitor would be collected. Following seven consecutive days of monitoring, the activity monitor data were downloaded via a reader interface unit to a personal computer for analysis. The activity monitor was worn for approximately 16 hours per day with the total amount of physical activity expressed as the average counts per minute (activity monitor count) of registered time.

#### 2.2.5.3 Physical Activity Data Analysis

**PAQ-C**

The PAQ-C was scored according to the following procedure:

Question 1: The mean of all activities on the checklist was taken to form a composite value for question 1. A value of one was assigned to responses of 'no'. A value of two was assigned to responses of '1-2'. A value of three was assigned to responses of '3-4'. A value of four was assigned to responses of ‘5-6’. And, a value of five was assigned to responses of ‘7 times or more’.

Questions 2 – 8: As per question 1, marked responses were assigned a value of 1, 2, 3, 4 or 5.

Question 10: The mean of all days of the week, again assigned a value of 1-5 with ‘1’ being the lowest level of activity and ‘5’ the highest, was taken to form a composite value for question 10.

A mean of the values from questions 1 to 8 and 10 was taken to gain the final PAQ-C score.

Question 9 was used to identify students who had unusual activity during the previous week, but was not used as part of the summary activity score. The question reads: Were you sick last week, or did anything prevent you from doing your normal physical activities?

**Activity Monitor**

Based on average counts per minute (activity monitor count), energy expenditure in terms of metabolic equivalent (MET) was calculated using the following age-specific equation:

METs = 2.757 + (0.0015 x activity monitor count) – (0.08957 x age (decimal years)) – (0.000038 x activity monitor count x age (decimal years)) (Freedson *et al.*, 1997).

The time spent in each intensity range was calculated based on the work of Trost *et al.* (2002) – see Table 1.1.

The following definitions were used to categorise physical activity intensity

- Light Activity < 3 METs
- Moderate Activity ≥ 3 to < 6 METs
- Vigorous Activity ≥ 6 to < 9 METs
- Extreme ≥ 9 METs.

### 2.2.6 Asthma Severity Questionnaire – ASQ

To stratify asthmatic participants as trivial, mild, moderate or severe, responses to questions 1 to 6 of the ASQ (Appendix C) were summed and the average was then calculated. Responses to question 7 were not included in the scoring procedure, nor were responses marked ‘don’t know’. In regard to questions 8 and 9, participants were instructed to consider the frequency and duration of exercise where they were uncomfortably out of breath and sweating. Asthma severity was then derived according to the scale of Rosier et al. (1994) – see Table 2.1. Throughout this thesis, the term ‘asthma severity’ is used in reference to the incremental scale of Rosier et al. (1994), while ‘asthma status’ is used to denote whether a group is clinically classed as asthmatic or non-asthmatic. Specifically, participants who were currently taking anti-asthma medication were deemed to have asthma, while all others were classified as non-asthmatic participants.

**Table 2.1 Rosier Asthma Severity Scale**

| | |
|---|---|
| Trivial | 1 – 4 |
| Mild | 5 – 9 |
| Moderate | 9 – 14 |
| Severe | > 15 |

(Rosier *et al.*, 1994)

### 2.2.7 Common Statistical Methods

Statistical analyses were conducted using *Stata* Version 8.0 (Stata Corporation, Texas, USA). Descriptive data are presented as mean and standard deviation unless specified otherwise. Variables discussed in Chapters 3 to 5 were treated using a one-sample Kolmogorov-Smirnov test to determine normal distribution. A detailed description of the one-sample Kolmogorov-Smirnov test and a graphical representation of a normal distribution (Figure 2.6) are provided in Appendix K: Chapter 2 Appendices. Specific statistical treatments will be outlined in each subsequent chapter and Appendix A.

### 2.2.8 Data Management

Participants were assigned a randomly-generated code number when data were entered into the database, thereby ensuring anonymity. Throughout Chapters 3 and 4, data were classified and presented according to grade and gender group, unless specified otherwise. Furthermore, in some instances in Chapters 3 and 4, physical activity and aerobic fitness data were stratified according to BMI category (normal weight, overweight/obese) (Cole *et al.*, 2000) or %BF category (normal weight, overweight/obese) (Taylor *et al.*, 2002). Some data in Chapter 4 were also stratified according to asthma severity (trivial, mild, moderate/severe) (Rosier *et al.*, 1994).

The energy expended in kilojoules (kJ) during the 6MRT was estimated from 6MRD values. Average oxygen consumption throughout the 6MRT was estimated as:

$\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$) = 3.5 + (6MRD (m) /6 x 0.2) (American College of Sports Medicine, 1995).

Average $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$) was then converted to units of litres per minute:

$\dot{V}O_2$ ($L.min^{-1}$) = $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$) x (fat free mass (kg)/1000)

Energy expended during the 6MRT was then estimated as:

Energy expended (kJ) = $\dot{V}O_2$ ($L.min^{-1}$) x 5.05 ($kcal.L^{-1}$) x 6 (minutes) x 4.186 ($kJ.kcal^{-1}$)

It should be noted that this equation is designed for adult application. However, given that this analysis was only carried out to determine if estimates of energy expenditure differed between normal and overweight/obese participants, the use of the equation was deemed applicable.

# Chapter 3 Relationship between Aerobic Fitness, Physical Activity and Body Composition in Children and Adolescents

## 3.1 Introduction

To date, the question of whether relationships exist between physical activity, aerobic fitness, and body composition in paediatric populations has caused much debate. While a positive relationship between physical activity and aerobic fitness is established in adults (Blair *et al.*, 1989; Young & Steinhardt, 1993; Anderson & Haraldsdottir, 1995), the relationship in children and adolescents is less clear. A review that summarised the research relating physical activity to aerobic fitness in adolescents (Morrow & Freedson, 1994) found a similar number of studies for and against a relationship. Morrow and Freedson reported a weak correlation value of 0.17 ($R^2 < 0.03$), and conceded that further work was needed to better determine the relationship between physical activity and aerobic fitness. Poor measurement techniques, a high level of aerobic fitness, and the lack of any real relationship were collectively proposed as possible reasons for the weak association reported. Furthermore, comparability between studies was limited due to the various testing methods used.

Although a decreased involvement in habitual physical activity is suggested to contribute to the increased prevalence of overweight and obesity (Magarey *et al.*, 2001), contradictory reports on the relationship between physical activity and body composition in children and adolescents are apparent. Two reviews focusing on the relationship between physical activity and body composition in children and adolescents (Bar-Or & Baranowski, 1994; Ward & Evans, 1995) found no consistent relationship between the two variables. However, it should be noted that many of the studies reviewed did not include an objective measure of physical activity. Importantly, a longitudinal paediatric investigation which employed objective activity monitoring for one week, twice per year over an eight-year period found that 11-year old children who were serially in the lowest tertile for activity had a greater sum of skinfolds and BMI compared to more active peers (Moore *et al.*, 2003). Despite this finding, obese and non-obese youngsters may have similar levels of energy expenditure (Bar-Or & Baranowski, 1994; Goran, 1997; Ekelund *et al.*, 2002; Ekelund *et al.*, 2004).

Additionally, some authors have reported an inverse relationship between adiposity and aerobic fitness in children and adolescents (Davies *et al.*, 1975; Nassis *et al.*, 2005), while others suggest the aerobic fitness of overweight and obese children and adolescents is comparable to their non-obese counterparts (Elliot *et al.*, 1989; Maffeis *et al.*, 1994). However, corrections for FFM often alter the outcome and must be considered.

As such, the aims of this chapter were, firstly, to establish whether any relationships exist between physical activity, aerobic fitness and body composition in a cross-sectional study of children and adolescents aged 10 to 14 years. As a consequence, the establishment of normative data for this population was a further purpose. In addition, this work also aimed to delineate the influence of age and gender on these variables.

## 3.2 Methodology

### 3.2.1 Participants

Six-hundred and thirty-five non-asthmatic grade 5 and grade 8 children and adolescents, aged 10 to 14 years, were recruited from a convenient sample of government, independent, and Catholic schools from metropolitan Melbourne. Testing occurred between 2001 and 2004.

### 3.2.2 Procedure

For time efficiency and to gain competitiveness in the 6MRT, participants completed the test battery in groups of six to eight. For more detailed information on procedures, see Chapters 2 (General Methodology).

To begin the selected testing protocols, stretched stature (standing height) was recorded to the nearest 0.1 cm using a portable stadiometer (Seca Model 214, Hamburg, Germany) and weight was measured to the nearest 0.1 kg using digital scales (Tanita BWB 600, Tanita Corp, Tokyo).

Skinfold thickness was recorded at four sites (Durnin & Rahaman, 1967) using Harpenden skinfold calipers (British Indicators Ltd, St Albans, Hertfordshire). Measurements were made with participants standing in the anatomical position and the calipers in direct contact with the skin (i.e. not through clothing). To ensure consistency, one experienced researcher performed all measurements and obtained two measurements for each site (Norton & Olds, 1996).

The validated tetrapolar method was employed to measure BIA, with two electrodes positioned on the participant's bare right hand and two electrodes on the subject's bare right foot (Lukaski *et al.*, 1986). Prior to measurement, the participant's height, weight, gender and age were entered into the Biodynamics® Model 310e (Biodynamics Corporation, Seattle, Washington). The electrodes fitted to the participant were then connected to the BIA device via electrical wiring and alligator clips. The analyser then generated values of bio-resistance and % BF (Biodynamics Corporation, 2000).

To ensure participants were eligible to complete the 6MRT, spirometry was performed using Jaeger® equipment (Jaeger, Würzburg, Germany). Participants were asked to stand and use a nose clip while performing the lung function manoeuvre. Participants were instructed to place their lips around the disposable cardboard mouthpiece, and following one or two preliminary breaths, to inhale as deeply as possible and then to exhale as hard and as fast as they could for as long as possible. Spirometry was conducted according to American Thoracic Society criteria (American Thoracic Society, 1995).

Prior to beginning the 6MRT, participants were also fitted with a Polar® Vantage NV heart rate monitor (Polar Electro Oy, Kempele, Finland). Heart rate data were used in the final 2-3 minutes of the test, to ensure that heart rate responses were greater than 85% of the participant's predicted maximal heart rate (West *et al.*, 1996), where predicted maximal heart rate was calculated as 210 – (0.65*age) (Spiro, 1977).

For the 6MRT, participants were instructed to pace themselves, yet were also informed they should aim to run the furthest distance possible. Verbal encouragement was constantly provided by the investigative team during the test, with the distance run in six minutes measured to the nearest 10-metre plastic cone.

The PAQ-C was administered after the 6MRT and was carried out in silence. Participants were seated apart and technical assistance was provided upon request.

A sub-sample of participants (n = 26) were also fitted with a programmed activity monitor prior to departing the testing session to gain an objective measure of physical activity. The activity monitor belt was positioned in accordance with the manufacturer's recommendations (ActiGraph, LLC, Fort Walton, Florida), and both verbal and written instructions (see Appendix F) for the correct use and care of the activity monitor were provided to the participant. Participants were instructed to wear the activity monitor during waking hours for seven consecutive days. For more detailed information on activity monitor procedures, see Section 2.2.5.

### 3.2.3 Data Management

Data were grouped according to grade and gender. Data for 6MRD were also expressed in terms of FFM to account for adiposity. Estimates of FFM were calculated using the %BF values generated from skinfold thickness measurements. Data for activity monitor counts were converted to estimated MET values, and time representations for each intensity range were also calculated (Trost, 2001). Physical activity and aerobic fitness data were also stratified according to BMI (Cole *et al.*, 2000) and %BF (Taylor *et al.*, 2002) categories in order to determine the specific influence of body composition on these parameters. Energy expended in kilojoules (kJ) during the 6MRT was estimated from 6MRD values (see Section 2.2.8, page 115) to assess whether any differences existed between normal and overweight/obese participants.

### 3.2.4 Statistical Analysis

Statistical analysis was performed using *Stata* Version 8.0 (Stata Corporation, Texas, USA). The one-sample Kolmogorov-Smirnov test was employed to test the normality of the data parameters under investigation. If data sets were not normally distributed, a log transformation was carried out and normality re-tested. All descriptive data were reported as mean and standard deviation. Unpaired (independent) *t* tests were used to test if population means estimated by two independent samples differed significantly. One-way analysis of variance (ANOVA) was employed to test for differences in a single dependent variable among three or more groups formed by the categories of a single independent categorical variable. Following the detection of a significant main effect, Sidak post-hoc analyses were performed to locate where specific mean differences lay. Regression analyses were performed to estimate the predictive power of an independent variable, such as BMI, on a dependent variable, such as 6MRD. Correlation analyses were also performed to determine the interdependence of two variables. Significance levels were set at $p<0.05$.

## 3.3 Results

### 3.3.1 Participants

A total of 635 grade 5 children and grade 8 adolescents participated in the study (Table 3.1). Age, height, mass, FM and FFM were all significantly greater among grade 8 groups when compared to grade 5 groups of corresponding gender. Grade 5 males had 17.1% lower FM ($t[326]=4.41$; $p<0.0001$) and 9.1% greater FFM ($t[326]=5.51$; $p<0.0001$) when compared to females of the same age. Similarly, grade 8 males had 30.5% lower FM ($t[305]=7.95$; $p<0.0001$) and 11.4% greater FFM ($t[305]=5.7$; $p<0.0001$) values when compared to females of the same age. In addition, grade 8 males were 1.5% taller than grade 8 females ($t[305]=2.75$; $p=0.006$). Results from the $FEV_1$ % predicted were within the normal healthy range for all children, with no significant differences found when comparing groups by age or gender.

**Table 3.1 Non-asthmatic participant characteristics**

| | Grade 5 Male (n=181) | Grade 5 Female (n=147) | Grade 8 Male (n=133) | Grade 8 Female (n=174) |
|---|---|---|---|---|
| **Age (years)** | $10.90 \pm 0.50^{\dagger}$ | $10.90 \pm 0.41^{\dagger}$ | $13.52 \pm 0.40$ | $13.80 \pm 0.50$ |
| **Height (cm)** | $146.5 \pm 6.4^{\dagger}$ | $146.4 \pm 7.3^{\dagger}$ | $163.6 \pm 8.8$* | $161.2 \pm 6.6$ |
| **Mass (kg)** | $40.2 \pm 8.6^{\dagger}$ | $39.3 \pm 7.5^{\dagger}$ | $54.9 \pm 11.9$ | $55.8 \pm 11.3$ |
| **FM (kg)** | $9.2 \pm 4.3^{*\dagger}$ | $11.1 \pm 3.6^{\dagger}$ | $12.1 \pm 5.9$* | $17.4 \pm 5.7$ |
| **FFM (kg)** | $31.0 \pm 4.8^{*\dagger}$ | $28.2 \pm 4.3^{\dagger}$ | $42.8 \pm 7.5$* | $38.4 \pm 6.0$ |
| **FM:FFM Ratio** | $0.35 \pm 0.11$ | $0.35 \pm 0.12$ | $0.37 \pm 0.12$ | $0.34 \pm 0.12$ |
| **$FEV_1$ (% predicted)** | $99.7 \pm 14.8$ | $98.3 \pm 11.5$ | $103.8 \pm 16.2$ | $104.0 \pm 13.1$ |

Mean ± SD

* significantly different from females of the same age ($p<0.05$)

† significantly different from grade 8 group of the same gender ($p<0.0001$)

## 3.3.2 Testing Data Distribution for Normality

Kolmogorov-Smirnov test results for all data parameters are shown in Table 3.2 (Appendix L: Chapter 3 Appendices). As highlighted in Appendix K: Chapter 2 Appendices, a Kolmogorov-Smirnov test significance value less than 0.05 demonstrates a detachment from normal distribution. The BMI data were not normally distributed (see Figure 3.1), however, a log transformation resulted in a normal distribution so reported BMI differences were based on transformed data (see Figure 3.2). All other variables listed were normally distributed.

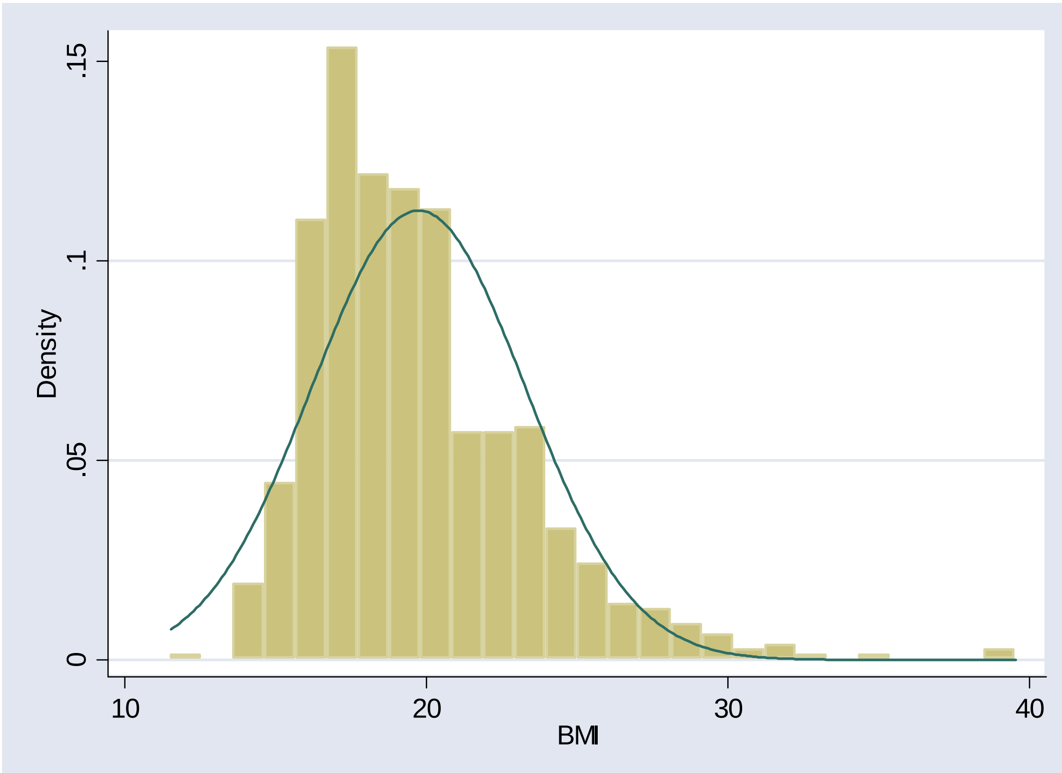



**Figure 3.1 Histogram of BMI data**

A representation of the frequency distribution of BMI data for non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years.

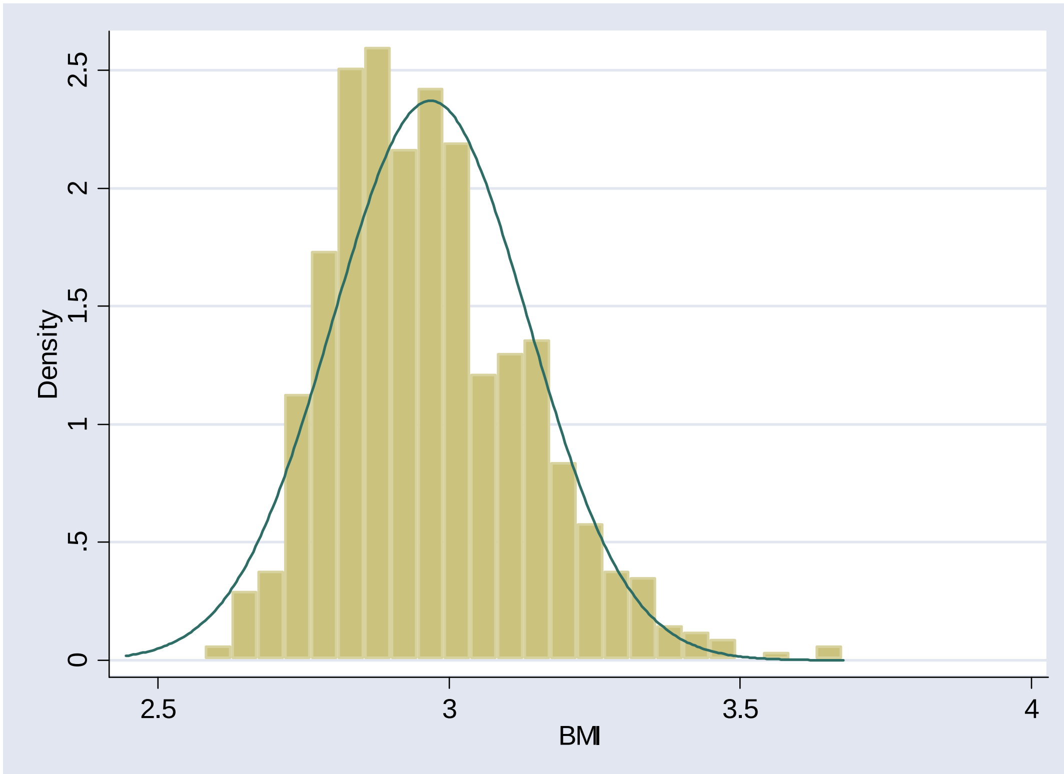



**Figure 3.2 Histogram of log-transformed BMI data**

Log-transformed representation of the frequency distribution of BMI data for non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years.

### 3.3.3 Body Composition – BMI, %BF

Mean BMI and %BF values are shown in Table 3.3. Grade 5 males and females had 9.1% lower (t[312]=4.75; p<0.0001) and 17.5% lower (t[319]=8.72; p<0.0001) BMI values, respectively, when compared to grade 8 groups of the same gender. Grade 8 males had a 4.7% lower (t[305]=2.47; p=0.01) mean BMI compared to grade 8 females. Grade 5 and 8 males had 26.5% lower (t=[326]=10.47; p<0.0001) and 41.0% lower (t[305]=15.57; p<0.0001) mean %BF values, respectively, when compared to females of the same age, while grade 5 females had a 10.1% lower (t[319]=5.82; p=0.0001) mean %BF value when compared to grade 8 females, who had the greatest %BF value overall.

**Table 3.3 Body composition characteristics of 10-14 year old non-asthmatic participants**

| | **Grade 5 Male** (n=181) | **Grade 5 Female** (n=147) | **Grade 8 Male** (n=133) | **Grade 8 Female** (n=174) |
|---|---|---|---|---|
| **BMI ($kg/m^2$)** | 18.61 ± 3.12$^{\dagger}$ | 18.23 ± 2.60$^{\dagger}$ | 20.38 ± 3.40* | 21.4 ± 3.70 |
| **% Body Fat** | 21.9 ± 5.50* | 27.7 ± 4.30$^{\dagger}$ | 21.7 ± 5.70* | 30.5 ± 4.20 |

Mean ± SD

* significantly different from females of the same age (p<0.05)

$^{\dagger}$ significantly different from grade 8 group of the same gender (p<0.001)

### 3.3.4 Aerobic Fitness & Heart Rate Responses

Mean 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and peak heart rate values are shown in Table 3.4. Grade 5 and 8 males recorded 10% greater ($t[326]=5.63$; $p<0.0001$) and 19.4% greater ($t[305]=10.26$; $p<0.0001$) mean 6MRD values, respectively, when compared to females of the same age. Grade 8 males had an 8% greater mean 6MRD value when compared to grade 5 males ($t[312]=4.37$; $p<0.0001$). There were no significant differences in 6MRD between grade 5 and 8 for females.

Grade 5 males and females had 27% greater ($t[312]=8.70$; $p<0.0001$) and 37% greater ($t[319]=12.88$; $p<0.0001$) 6MRD/FFM values, respectively, when compared to grade 8 groups of the same gender, and grade 8 males had an 8.2% greater mean 6MRD/FFM when compared to grade 8 females ($t[305]=3.10$; $p=0.002$). The grade and gender differences in 6MRD/FFM values are illustrated in Figure 3.3.

Grade 5 and 8 males had 5.1% greater ($t[326]=3.84$; $p=0.0001$) and 13% greater ($t[305]=8.57$; $p<0.0001$) predicted peak $\dot{V}O_2$ values, respectively, when compared to females of the same age, and grade 8 females had a 7.3% lower peak $\dot{V}O_2$ value when compared to grade 5 females ($t[319]=6.02$; $p=0.0001$).

No differences were observed in peak heart rate between grade and gender groups. For the current sample, 94.7% and 90.8% achieved a peak heart rate above 85% and 90% of their predicted maximum, respectively. Participants who did not exceed the 85% predicted maximum threshold were still included in subsequent analyses if the 6MRT had been completed satisfactorily.

**Table 3.4 Aerobic fitness of 10-14 year old non-asthmatic participants**

| | **Grade 5 Male** (n=181) | **Grade 5 Female** (n=147) | **Grade 8 Male** (n=133) | **Grade 8 Female** (n=174) |
|---|---|---|---|---|
| **6MRD (m)** | 1106 ± 169.2*† | 1005.0 ± 151.7 | 1194.2 ± 186.2* | 1000.0 ± 144.6 |
| **6MRD/FFM (m/kg)** | 36.6 ± 8.1† | 36.5 ± 7.7† | 28.9 ± 6.9* | 26.7 ± 5.9 |
| **Predicted Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 47.3 ± 5.6* | 45.0 ± 5.0† | 47.1 ± 6.2* | 41.7 ± 4.8 |
| **Heart Rate (bpm)** | 196.4 ± 9.2 | 194.8 ± 11.7 | 195.5 ± 9.1 | 193.6 ± 9.8 |
| **% Predicted Maximum Heart Rate** | 96.7 ± 0.60 | 96.0 ± 0.72 | 97.2 ± 0.58 | 96.3 ± 0.67 |

Mean ± SD

* significantly different from females of the same age ($p<0.05$)

† significantly different from grade 8 group of the same gender ($p < 0.001$)

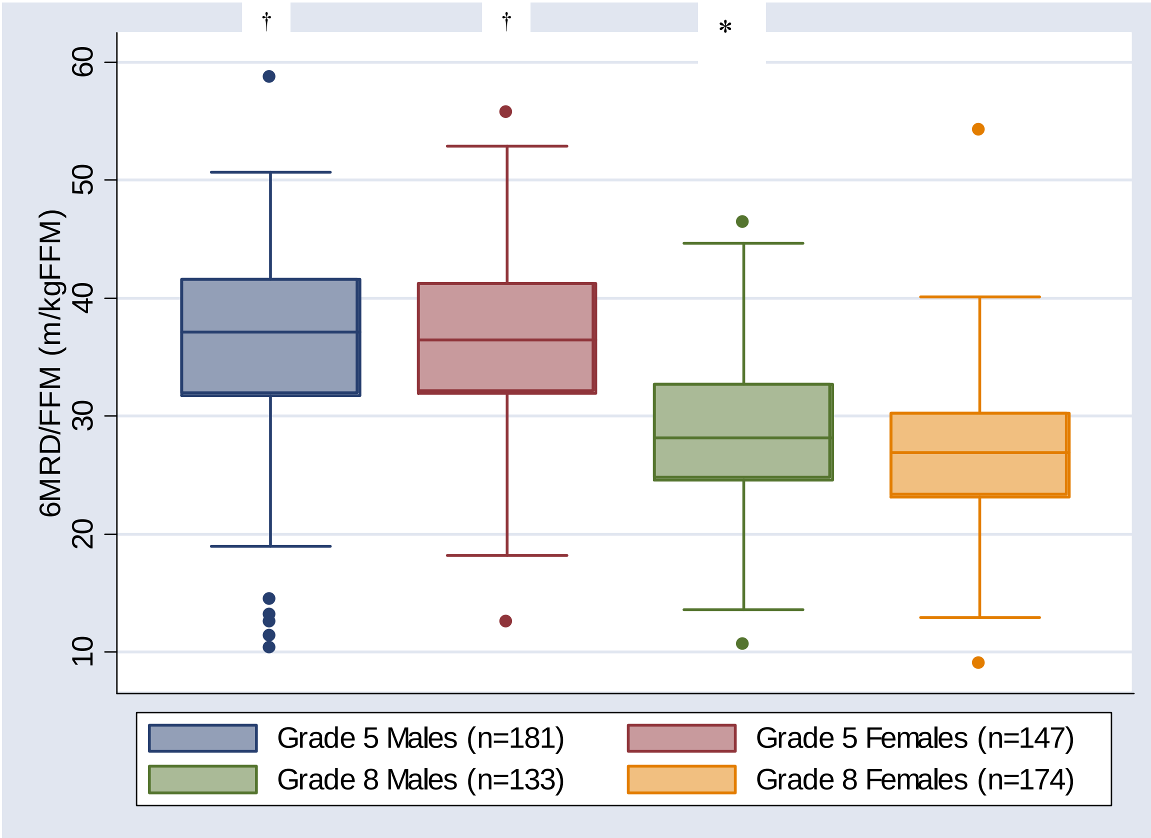



**Figure 3.3 Comparison of 6MRD/FFM between grade and gender groups**

Box-whisker plots of 6MRD/FFM values grouped by grade and gender in non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years. Plots show the mean and 95% confidence intervals. Outliers represent those values outside the 95% confidence interval.

6MRD/FFM = Six minute running distance per kilogram of fat free mass

* significantly different from females of the same age ($p<0.05$)

† significantly different from grade 8 group of the same gender ($p < 0.001$)

### 3.3.5 Physical Activity Measures – PAQ-C, Activity Monitor Counts & Estimated MET

Mean PAQ-C, activity monitor counts and estimated MET values are shown in Table 3.5. Grade 5 males and females had 14.5% greater ($t[312]=5.89$; $p<0.0001$) and 22.6% greater ($t[319]=8.25$; $p<0.0001$) PAQ-C values, respectively, when compared to grade 8 groups of the same gender, while grade 5 and 8 males had 11.5% greater ($t[326]=4.99$; $p<0.0001$) and 19.4% greater ($t[305]=6.97$, $p<0.0001$) PAQ-C scores, respectively, compared to females of the same age.

No activity monitor count differences were observed between grades or genders ($p>0.05$), however, grade 5 males and females had 20.5% ($t[312]=5.90$; $p<0.0001$) and 22.6% greater ($t[319]=8.25$; $p<0.0001$) mean estimated MET values, respectively, when compared to grade 8 groups of the same gender. Furthermore, grade 8 males had an 11.1% greater mean estimated MET value in comparison with grade 8 females ($t[10]=2.64$; $p=0.02$). These differences in estimated MET values are depicted in Figure 3.4.

**Table 3.5 Physical activity of 10-14 year old non-asthmatic participants**

| | **Grade 5 Male** | **Grade 5 Female** | **Grade 8 Male** | **Grade 8 Female** |
|---|---|---|---|---|
| **PAQ-C (index)** | 3.39 ± 0.65*† (n = 181) | 3.04 ± 0.64† (n = 147) | 2.96 ± 0.64* (n = 133) | 2.48 ± 0.57 (n = 174) |
| **Activity monitor counts (counts/min)** | 585.3 ± 270.3 (n = 6) | 332.2 ± 86.8 (n = 8) | 440.5 ± 129.8 (n = 6) | 305.4 ± 146.8 (n = 6) |
| **Estimated MET ($ml.kg^{-1}.min^{-1}$)** | 2.41 ± 0.41† (n = 6) | 2.14 ± 0.10† (n = 8) | 2.00 ± 0.13* (n = 6) | 1.80 ± 0.13 (n = 6) |

Mean ± SD

* significantly different from females of the same age (p<0.05)

† significantly different from grade 8 group of the same gender (p<0.05)

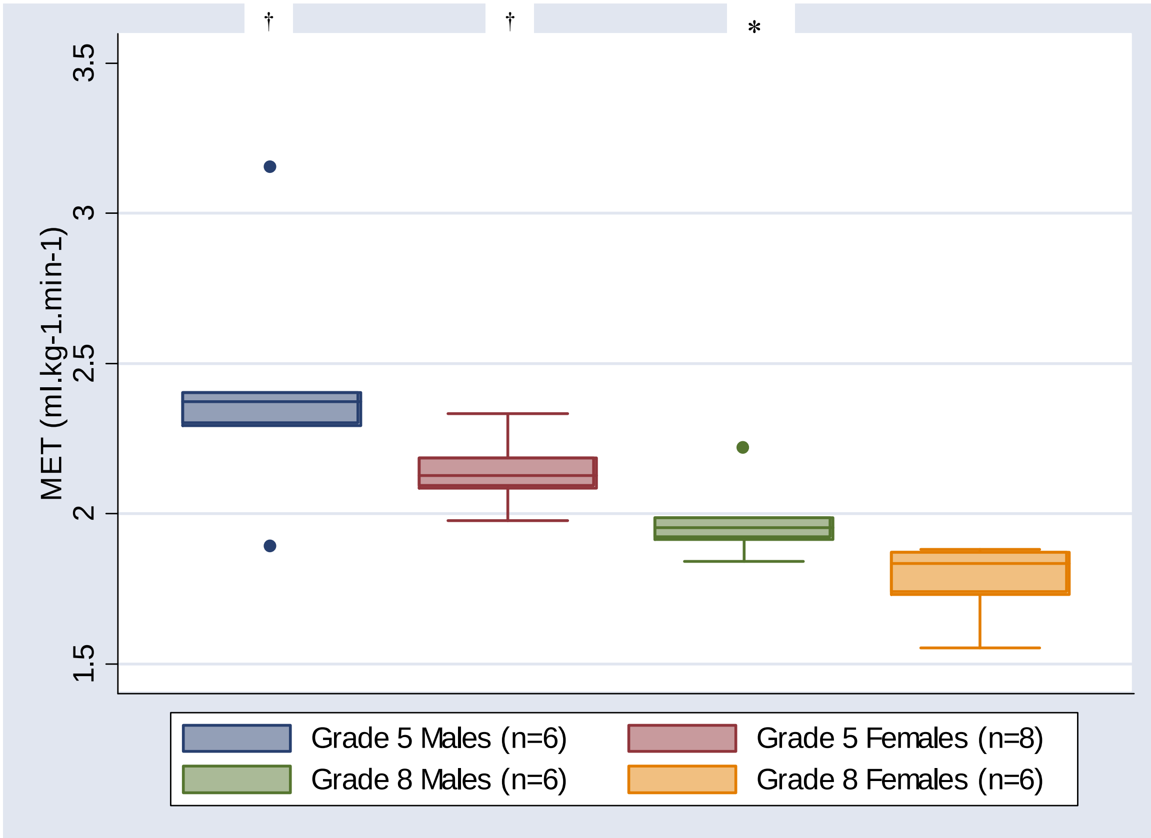



**Figure 3.4 Comparison of estimated metabolic equivalent values between grade and gender groups**

Box-whisker plots of estimated MET values grouped by grade and gender in non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years. Plots show the mean and 95% confidence intervals. Outliers represent those values outside the 95% confidence interval.

MET = metabolic equivalent.

* significantly different from females of the same age ($p<0.05$)

† significantly different from grade 8 group of the same gender ($p<0.05$)

In accordance with age-specific thresholds (Trost, 2001) (see Table 1.1), results for the amount of time spent in each physical activity intensity range, along with the proportion of time spent at each intensity, are shown in Table 3.6a. In addition, the physical activity intensity data categorised by body composition status are shown in Table 3.6b. Grade 5 males spent 19.6% less time in the light intensity range when compared to grade 5 females ($t[12]=2.55$; $p=0.03$). Furthermore, grade 5 males spent significantly more time in the extreme intensity range than any other grade or gender group. There were no differences between normal weight and overweight/obese participants in terms of time spent in physical activity intensity ranges, when classified by the BMI cutoff points of Cole *et al*. (2000) or the %BF cutoff points of Taylor *et al*. (2002), (see Table 3.6b).

**Table 3.6a Amount of time and proportion of time spent in daily physical activity classified by intensity range#**

| | Grade 5 Male (n=6) | Grade 5 Female (n=8) | Grade 8 Male (n=6) | Grade 8 Female (n=6) |
|---|---|---|---|---|
| **Light (mins/day)** | 430.8 ± 72.5* | 536.0 ± 78.9 | 411.0 ± 77.2 | 517.3 ± 199.1 |
| **Time %** | 44.9* | 55.8 | 42.8 | 54.4 |
| **Moderate (mins/day)** | 396.1 ± 59.1 | 334.5 ± 65.8 | 464.2 ± 48.9 | 377.5 ± 165.7 |
| **Time %** | 41.3 | 34.8 | 48.4 | 39.3 |
| **Vigorous (mins/day)** | 91.2 ± 27.8 | 77.1 ± 28.9 | 71.6 ± 33.6 | 54.4 ± 19.5 |
| **Time %** | 9.5 | 8.1 | 7.5 | 5.7 |
| **Extreme (mins/day)** | 41.9 ± 24.1† | 12.4 ± 7.5 | 13.2 ± 8.3 | 5.5 ± 4.8 |
| **Time %** | 4.3† | 1.3 | 1.3 | 0.6 |

Mean ± SD

* significantly different from females of the same age (p<0.05)

† significantly different from all other groups (p<0.01)

# Intensity ranges based on (Trost, 2001)

**Table 3.6b Amount of time and proportion of time spent in daily physical activity classified by intensity range[#], with respect to body composition**

| | **Normal BMI** (n = 15) | **Overweight/Obese BMI** (n = 11) | **Normal %BF** (n = 11) | **Overweight/Obese %BF** (n = 15) |
|---|---|---|---|---|
| **Light (mins/day)** | 458.1 ± 75.0 | 456.4 ± 167.6 | 439.9 ± 76.8 | 446.9 ± 143.1 |
| **Time %** | 47.7 | 47.5 | 45.8 | 46.6 |
| **Moderate (mins/day)** | 410.6 ± 75.1 | 410.6 ± 128.1 | 431.2 ± 76.6 | 420.2 ± 110.1 |
| **Time %** | 42.8 | 42.8 | 44.9 | 43.7 |
| **Vigorous (mins/day)** | 73.5 ± 25.1 | 75.2 ± 35.7 | 72.1 ± 23.6 | 74.9 ± 33.7 |
| **Time %** | 7.6 | 7.7 | 7.5 | 7.8 |
| **Extreme (mins/day)** | 17.8 ± 13.2 | 17.8 ± 24.6 | 16.8 ± 13.9 | 18.0 ± 21.6 |
| **Time %** | 1.9 | 1.9 | 1.8 | 1.9 |

Cole *et al*. (2000) Taylor *et al*. (2002)

[#] Intensity ranges based on (Trost, 2001)

### 3.3.6 Relationship between Activity Monitor Counts and PAQ-C

Results for the relationship between activity monitor counts and the PAQ-C are shown in Table 3.7. Grade 5 males demonstrated an inverse association while all other groups produced positive associations. However, none of these results reached significance.

**Table 3.7 Association between activity monitor counts and the PAQ-C**

| | **Grade 5 Male** (n=6) | **Grade 5 Female** (n=8) | **Grade 8 Male** (n=6) | **Grade 8 Female** (n=6) |
|---|---|---|---|---|
| **Activity monitor counts (counts/min)** | 585.3 ± 270.3 (n = 6) | 332.2 ± 86.8 (n = 8) | 440.5 ± 129.8 (n = 6) | 305.4 ± 146.8 (n = 6) |
| **PAQ-C (index)** | 3.90 ± 0.66 | 2.47 ± 0.37 | 3.00 ± 0.56 | 2.65 ± 0.61 |
| **Pearson's r** | -0.22 | 0.59 | 0.33 | 0.53 |

Mean ± SD

### 3.3.7 Relationship between Aerobic Fitness and Body Composition

#### 3.3.7.1 Aerobic fitness, stratified according to the BMI categories of Cole *et al*. (2000)

The mean results for the variables of 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and peak heart rate, categorised by gender- and age-specific BMI cutoff points (Cole *et al*., 2000), are shown in Table 3.8, with regression analysis findings displayed in Table 3.9 (Appendix L: Chapter 3 Appendices). The low number of participants classified as obese resulted in overweight- and obese-classified participants being analysed as a single group.

**Table 3.8 Aerobic fitness and heart rate responses stratified according to the BMI categories of Cole *et al*. (2000)**

| Group | Variable | Normal BMI | Overweight/Obese BMI |
|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | 1141.5 ± 149.9* | 980.9 ± 175.6 |
| | **6MRD/FFM** (m/kgFFM) | 39.3 ± 6.4* | 27.1 ± 5.93 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 48.5 ± 5.0* | 43.2 ± 5.8 |
| | **Heart Rate** (bpm) | 196.6 ± 9.4 | 196.0 ± 8.6 |
| | | (n = 141) | (n = 40) |
| **Grade 5 Females** | **6MRD** (m) | 1021.9 ± 140.1* | 898.0 ± 176.1 |
| | **6MRD/FFM** (m/kgFFM) | 38.1 ± 6.5* | 26.4 ± 6.8 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 45.6 ± 4.7* | 41.5 ± 5.8 |
| | **Heart Rate** (bpm) | 195.0 ± 11.1 | 195.0 ± 15.2 |
| | | (n = 127) | (n = 20) |
| **Grade 8 Males** | **6MRD** (m) | 1224.0 ± 172.7 | 1088.6 ± 196.3 |
| | **6MRD/FFM** (m/kgFFM) | 30.9 ± 6.1* | 22.1 ± 4.9 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 48.1 ± 5.7* | 43.6 ± 6.5 |
| | **Heart Rate** (bpm) | 196.0 ± 8.6 | 195.2 ± 10.4 |
| | | (n = 103) | (n = 30) |
| **Grade 8 Females** | **6MRD** (m) | 1028.0 ± 138.1* | 917.7 ± 133.3 |
| | **6MRD/FFM** (m/kgFFM) | 28.6 ± 5.1* | 20.9 ± 4.1* |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 42.6 ± 4.6* | 39.0 ± 4.4 |
| | **Heart Rate** (bpm) | 194.2 ± 9.7 | 192.0 ± 10.0 |
| | | (n = 129) | (n = 45) |

Mean ± SD

* significantly different from the overweight/obese group of the same variable, age and gender ($p<0.05$)

Grade 5 males and females in the normal BMI group had 16.4% greater ($t[179]=5.75$; $p<0.0001$) and 13.8% greater ($t[145]=3.53$; $p=0.0006$) 6MRD values, respectively, when compared to the corresponding overweight/obese group. Similarly, grade 8 males and females in the normal BMI group had 12.4% greater ($t[131]=3.62$; $p=0.0004$) and 12.0% greater ($t[172]=4.62$; $p<0.0001$) 6MRD values, respectively, than participants in the corresponding overweight/obese BMI group.

Grade 5 males and females in the normal BMI group had 45.0% greater ($t[179]=10.84$; $p<0.0001$) and 44.3% greater ($t[145]=7.36$; $p<0.0001$) 6MRD/FFM values, respectively, when compared to the overweight/obese group of the same gender. Likewise, grade 8 males and females in the normal BMI group had 39.8% greater ($t[131]=7.17$; $p<0.0001$) and 36.8% greater ($t[172]=9.09$; $p<0.0001$) 6MRD/FFM values, respectively, when compared to participants in the corresponding overweight/obese BMI group.

Grade 5 males and females who fell in the normal BMI range had 12.3% greater ($t[179]=5.75$; $p<0.0001$) and 44.3% greater ($t[145]=3.52$; $p=0.0006$) predicted peak $\dot{V}O_2$ values, respectively, when compared to those in the corresponding overweight/obese group. In a similar fashion, grade 8 males and females in the normal BMI group had 10.3% greater ($t[131]=3.61$; $p=0.0004$) and 9.2% greater ($t[172]=4.62$; $p<0.0001$) predicted peak $\dot{V}O_2$ values than participants in the corresponding overweight/obese BMI group.

Regression analysis demonstrated significant inverse associations between 6MRD and BMI, 6MRD/FFM and BMI, and predicted peak $\dot{V}O_2$ and BMI for each grade and gender group.

Figure 3.5 shows the inverse association between 6MRD/FFM and BMI within a grade and gender grouping, while Figure 3.6 demonstrates the overall inverse association between BMI and measures of aerobic fitness for the combined data set. No differences in heart rate between BMI strata were observed ($p>0.05$).

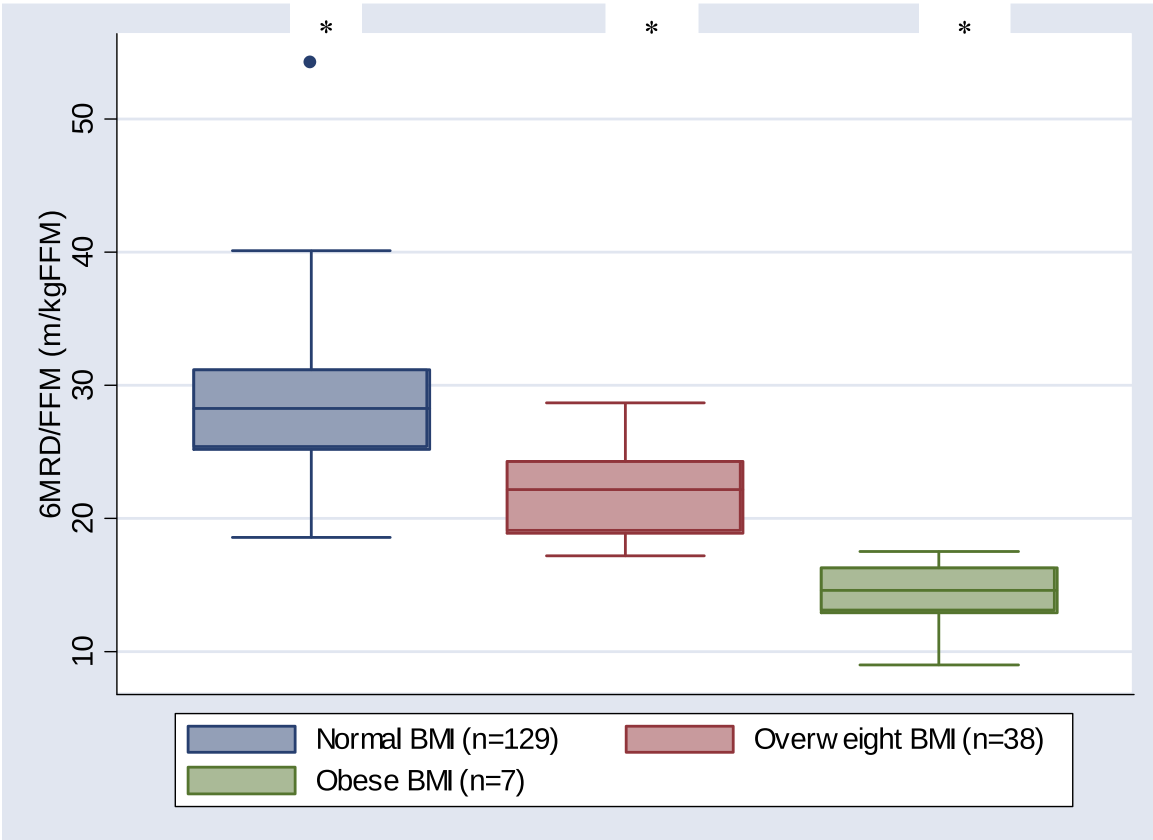



**Figure 3.5 Comparison of 6MRD/FFM in grade 8 females grouped according to BMI category** (Cole *et al*., 2000)

Box-whisker plots of 6MRD/FFM values grouped by BMI category (i.e. normal, overweight, obese) in 174 non-asthmatic grade 8 females aged 12-14 years. Plots show the mean and 95% confidence intervals. Outliers represent those values outside the 95% confidence interval. 6MRD/FFM = six minute running distance per kilogram of fat free mass.

* significantly different from other BMI classification groups of the same variable, age and gender ($p<0.05$)

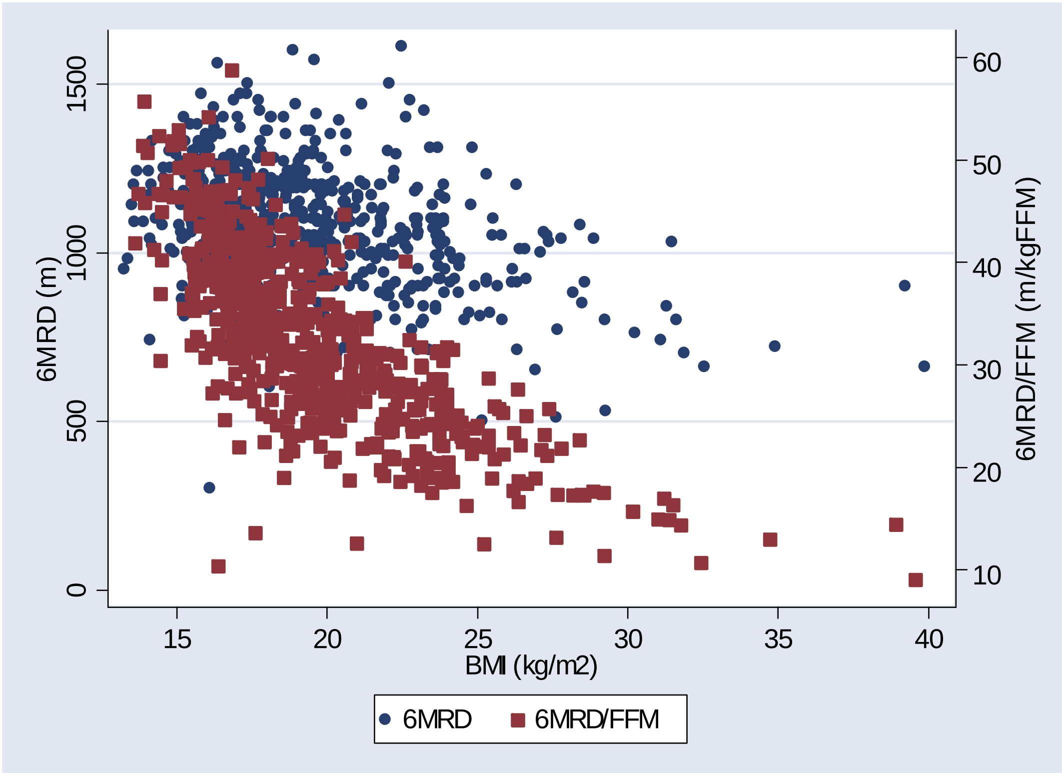



**Figure 3.6 Scatterplots of aerobic fitness measures versus BMI**

Scatterplots demonstrate the inverse relationship between 6MRD and BMI, and between 6MRD/FFM and BMI in a total of 635 non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years. 6MRD = six minute running distance; 6MRD/FFM = six minute running distance per kilogram of fat free mass.

Regression analysis equations for the combined data set (n=635):

6MRD = -18.3 (BMI) + 1431.0 ($R^2$=0.13; p<0.0001)

6MRD/FFM = -1.81 (BMI) + 67.8 ($R^2$=0.56; p<0.0001)

#### 3.3.7.1.1 Estimated energy expenditure (kJ), stratified according to BMI categories of Cole *et al*. (2000)

For each grade and gender group, the estimated energy expended in completion of the 6MRT, as calculated from the equation shown in Section 2.2.8 (page 116), was significantly greater among overweight/obese participants when compared to their normal weight-for-age counterparts. Specifically, grade 5 males and females who were classified as overweight/obese had 9.2% greater (t[179]=2.97; p=0.003) and 12.1% greater (t[145]=2.57; p=0.01) estimated energy expenditure values, respectively, when compared to age-matched participants in the normal BMI category. In a similar fashion, grade 8 males and females who fell into the overweight/obese BMI range had 10.1% greater (t[131]=2.27; p=0.02) and 10.5% greater (t[172]=3.47; p=0.0007) estimated energy expenditure values, respectively, when compared to participants of the same age in the normal BMI category. Estimated energy expenditure values are shown in Table 3.10.

**Table 3.10 Estimated energy expenditure (kJ) calculated from six-minute running test distances – stratified according to the BMI categories of Cole *et al*. (2000)**

| Group | Estimated energy expenditure for participants with a BMI classified as normal (kJ) | Estimated energy expenditure for participants with a BMI classed as overweight/obese (kJ) |
|---|---|---|
| **Grade 5 Males** | 154.6 ± 24.8* (n = 141) | 168.8 ± 28.3 (n = 40) |
| **Grade 5 Females** | 130.0 ± 25.5* (n = 127) | 145.8 ± 24.4 (n = 20) |
| **Grade 8 Males** | 229.2 ± 47.2* (n = 103) | 252.4 ± 43.3 (n = 30) |
| **Grade 8 Females** | 174.2 ± 35.7* (n = 129) | 192.5 ± 28.1 (n = 45) |

Mean ± SD

*significantly different from the overweight/obese BMI group (p<0.03)

### 3.3.7.2 Aerobic fitness, stratified according to the %BF categories of Taylor *et al.* (2002)

Mean 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and peak heart rate values stratified according to the age- and gender-specific %BF cutoff points (Taylor *et al.*, 2002) are shown in Table 3.11, with regression analysis results displayed in Table 3.12 (Appendix L: Chapter 3 Appendices). The low number of participants classified as obese resulted in overweight- and obese-classified participants being analysed as a single group.

Grade 5 males and females who were classified within the normal BMI category had 13.6% greater ($t[179]=6.04$; $p<0.0001$) and 14.8% greater ($t[145]=5.32$; $p<0.0001$) 6MRD values, respectively, when compared to overweight/obese groups of corresponding gender. Similarly, grade 8 males and females in the normal BMI category had 18% greater ($t[131]=6.65$; $p<0.0001$) and 17.5% greater ($t[172]=6.45$; $p<0.0001$) 6MRD values when compared to the corresponding overweight/obese groups.

Grade 5 males and females in the normal BMI category had 26.5% greater ($t[179]=8.57$; $p<0.0001$) and 27.1% greater ($t[145]=6.91$; $p<0.0001$) 6MRD/FFM values, respectively, when compared to the overweight/obese group of the same gender. Also, grade 8 males and females had 26.7% ($t[131]=5.87$; $p<0.0001$) and 35.4% greater ($t[172]=7.92$; $p<0.0001$) 6MRD/FFM values, respectively, when compared to overweight/obese groups of corresponding gender.

Grade 5 males and females in the normal BMI category had 9.8% ($t[179]=5.91$; $p<0.0001$) and 10.5% greater ($t[145]=5.32$; $p<0.0001$) predicted peak $\dot{V}O_2$ values, respectively, when compared to males and females of the same age who were classified as overweight/obese. Grade 8 males and females who fell into the normal BMI range had 14.8% greater ($t[131]=6.65$; $p<0.0001$) and 13.5% greater ($t[172]=6.45$; $p<0.0001$) predicted peak $\dot{V}O_2$ values, respectively, when compared to males and females of the same age who fell into the overweight/obese category.

No differences in peak heart rate values were observed within any grade and gender group between %BF strata.

Regression analysis demonstrated significant inverse associations between 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and %BF for each grade and gender group. Figure 3.7 demonstrates the overall inverse association between %BF and measures of aerobic fitness for the combined data set.

**Table 3.11 Aerobic fitness and heart rate responses as categorised by %BF strata of Taylor *et al*. (2002)**

| Group | Variable | Normal %BF | Overweight/Obese %BF |
|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | 1168.5 ± 155.0* | 1029.0 ± 154.4 |
| | **6MRD/FFM** (m/kgFFM) | 40.5 ± 6.4* | 32.0 ± 7.3 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 49.4 ± 5.1* | 45.0 ± 4.8 |
| | **Heart Rate** (bpm) | 196.5 ± 9.2 | 196.4 ± 9.3 |
| | | (n = 100) | (n = 81) |
| **Grade 5 Females** | **6MRD** (m) | 1044.3 ± 132.4* | 910 ± 154.5 |
| | **6MRD/FFM** (m/kgFFM) | 38.9 ± 6.5* | 30.6 ± 7.1 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 46.3 ± 4.4* | 41.9 ± 5.1 |
| | **Heart Rate** (bpm) | 195.3 ± 11.3 | 193.7 ± 12.7 |
| | | (n = 104) | (n = 43) |
| **Grade 8 Males** | **6MRD** (m) | 1266.0 ± 164.3* | 1072.7 ± 156.2 |
| | **6MRD/FFM** (m/kgFFM) | 31.3 ± 6.1* | 24.7 ± 6.4 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 49.5 ± 5.5* | 43.1 ± 5.2 |
| | **Heart Rate** (bpm) | 195.8 ± 9.0 | 195.0 ± 9.2 |
| | | (n = 84) | (n = 49) |
| **Grade 8 Females** | **6MRD** (m) | 1033.8 ± 134.1* | 879.7 ± 114.5 |
| | **6MRD/FFM** (m/kgFFM) | 28.3 ± 5.2* | 20.9 ± 4.4 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 42.8 ± 4.5* | 37.7 ± 3.8 |
| | **Heart Rate** (bpm) | 194.1 ± 10.5 | 190.2 ± 10.5 |
| | | (n = 136) | (n = 38) |

Mean ± SD

* significantly greater than the overweight/obese group within the same variable, age and gender ($p<0.02$)

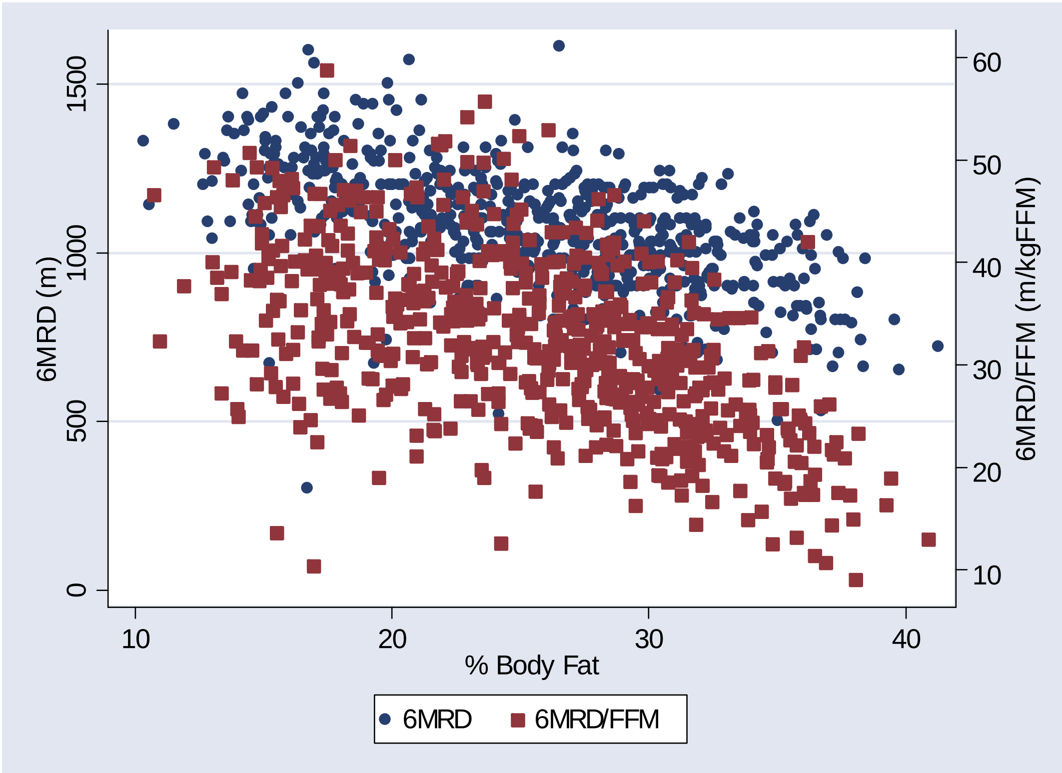



**Figure 3.7 Scatterplots of aerobic fitness measures versus %BF**

Scatterplots demonstrate the inverse relationship between 6MRD and %BF, and between 6MRD/FFM and %BF in a total of 635 non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years. 6MRD = six minute running distance; 6MRD/FFM = six minute running distance per kilogram of fat free mass.

Regression analysis equations for the combined data set (n=635):

6MRD = -17.0 (%BF) + 1506.7 ($R^2$=0.35; p<0.0001)

6MRD = -0.74 (%BF) + 51.1 ($R^2$=0.29; p<0.0001)

### 3.3.8 Relationship between Aerobic Fitness and Physical Activity

#### 3.3.8.1 Aerobic fitness and PAQ-C

Correlation analysis results and regression analysis results for the relationships between 6MRD and PAQ-C, 6MRD/FFM and PAQ-C, and predicted peak $\dot{V}O_2$ and PAQ-C are shown in Table 3.13 and Table 3.14, respectively. Each grade and gender group demonstrated significant positive associations between the three measures of aerobic fitness and PAQ-C, except for the association between 6MRD/FFM and PAQ-C in grade 5 females which failed narrowly to reach significance (p=0.06). An illustration of predicted peak $\dot{V}O_2$ versus PAQ-C is shown in Figure 3.8.

### Table 3.13 Correlation analysis for aerobic fitness versus PAQ-C

| Group | Variable | Pearson's r | p |
|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | 0.30 | 0.001 |
| **n=181** | **6MRD/FFM** (m/kgFFM) | 0.21 | 0.04 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 0.30 | 0.001 |
| **Grade 5 Females** | **6MRD** (m) | 0.25 | 0.002 |
| **n=147** | **6MRD/FFM** (m/kgFFM) | 0.15 | 0.06 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 0.25 | 0.002 |
| **Grade 8 Males** | **6MRD** (m) | 0.33 | 0.002 |
| **n=133** | **6MRD/FFM** (m/kgFFM) | 0.20 | 0.04 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 0.33 | 0.002 |
| **Grade 8 Females** | **6MRD** (m) | 0.33 | 0.001 |
| **n=174** | **6MRD/FFM** (m/kgFFM) | 0.18 | 0.02 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 0.33 | 0.001 |

**Table 3.14 Regression analysis for aerobic fitness and PAQ-C**

| Group | PAQ-C = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males** | 0.001 (6MRD) + 2.11 | 0.09 | 0.001 |
| **n=181** | 0.02 (6MRD/FFM) + 2.79 | 0.04 | 0.04 |
| | 0.04 (Predicted Peak $\dot{V}O_2$) + 1.74 | 0.09 | 0.001 |
| **Grade 5 Females** | 0.001 (6MRD) + 1.96 | 0.06 | 0.002 |
| **n=147** | 0.01 (6MRD/FFM) + 2.57 | 0.02 | 0.06 |
| | 0.03 (Predicted Peak $\dot{V}O_2$) + 1.58 | 0.06 | 0.002 |
| **Grade 8 Males** | 0.001 (6MRD) + 1.61 | 0.11 | 0.002 |
| **n=133** | 0.02 (6MRD/FFM) + 2.42 | 0.04 | 0.04 |
| | 0.03 (Predicted Peak $\dot{V}O_2$) + 1.36 | 0.11 | 0.002 |
| **Grade 8 Females** | 0.001 (6MRD) + 1.19 | 0.11 | 0.001 |
| **n=174** | 0.02 (6MRD/FFM) + 2.02 | 0.03 | 0.02 |
| | 0.04 (Predicted Peak $\dot{V}O_2$) + 0.86 | 0.11 | 0.001 |

### 3.3.8.2 Aerobic fitness and activity monitor counts

Correlation analysis results and regression analysis results for the relationships between activity monitor counts and 6MRD, 6MRD/FFM, and predicted peak $\dot{V}O_2$ are shown in Table 3.15 and Table 3.16, respectively. Both positive and inverse associations were observed however, none of the associations reached significance. It should be noted that the 11 overweight/obese participants who wore the activity monitor also demonstrated the inverse relationship between measures of aerobic fitness and markers of body fat seen in this chapter (Section 3.3.7). That is to say, they were not significantly fitter than those overweight/obese participants who did not wear an activity monitor. The association between predicted peak $\dot{V}O_2$ and activity monitor counts is shown in Figure 3.8.

**Table 3.15 Correlation analysis for aerobic fitness versus activity monitor counts**

| Group | Variable | Pearson's r | p |
|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | 0.06 | 0.92 |
| **n=6** | **6MRD/FFM** (m/kgFFM) | -0.71 | 0.11 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.06 | 0.92 |
| **Grade 5 Females** | **6MRD** (m) | 0.50 | 0.21 |
| **n=8** | **6MRD/FFM** (m/kgFFM) | 0.52 | 0.18 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.50 | 0.21 |
| **Grade 8 Males** | **6MRD** (m) | -0.60 | 0.21 |
| **n=6** | **6MRD/FFM** (m/kgFFM) | -0.58 | 0.23 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | -0.60 | 0.21 |
| **Grade 8 Females** | **6MRD** (m) | 0.78 | 0.07 |
| **n=6** | **6MRD/FFM** (m/kgFFM) | 0.78 | 0.06 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.78 | 0.07 |
| **Combined Data** | **6MRD** (m) | 0.36 | 0.07 |
| **n=26** | **6MRD/FFM** (m/kgFFM) | 0.21 | 0.31 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.36 | 0.07 |

**Table 3.16 Regression analysis for aerobic fitness and activity monitor counts**

| Group | Activity Monitor Counts = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males** | 0.13 (6MRD) + 433.0 | 0.003 | 0.92 |
| **n=6** | -66.8 (6MRD/FFM) + 300.8 | 0.50 | 0.11 |
| | 3.9 (Predicted Peak $\dot{V}O_2$) + 391.0 | 0.003 | 0.92 |
| **Grade 5 Females** | 0.19 (6MRD) + 161.7 | 0.25 | 0.21 |
| **n=8** | 4.50 (6MRD/FFM) + 205.5 | 0.27 | 0.18 |
| | 5.6 (Predicted Peak $\dot{V}O_2$) +96.0 | 0.25 | 0.21 |
| **Grade 8 Males** | -0.73 (6MRD) + 135.2 | 0.36 | 0.21 |
| **n=6** | -11.6 (6MRD/FFM) + 770.1 | 0.34 | 0.23 |
| | -21.8 (Predicted Peak $\dot{V}O_2$) + 151.4 | 0.36 | 0.21 |
| **Grade 8 Females** | 0.68 (6MRD) – 392.1 | 0.61 | 0.07 |
| **n=6** | -16.8 (6MRD/FFM) -142.5 | 0.61 | 0.06 |
| | 20.7 (Predicted Peak $\dot{V}O_2$) – 568.0 | 0.61 | 0.07 |

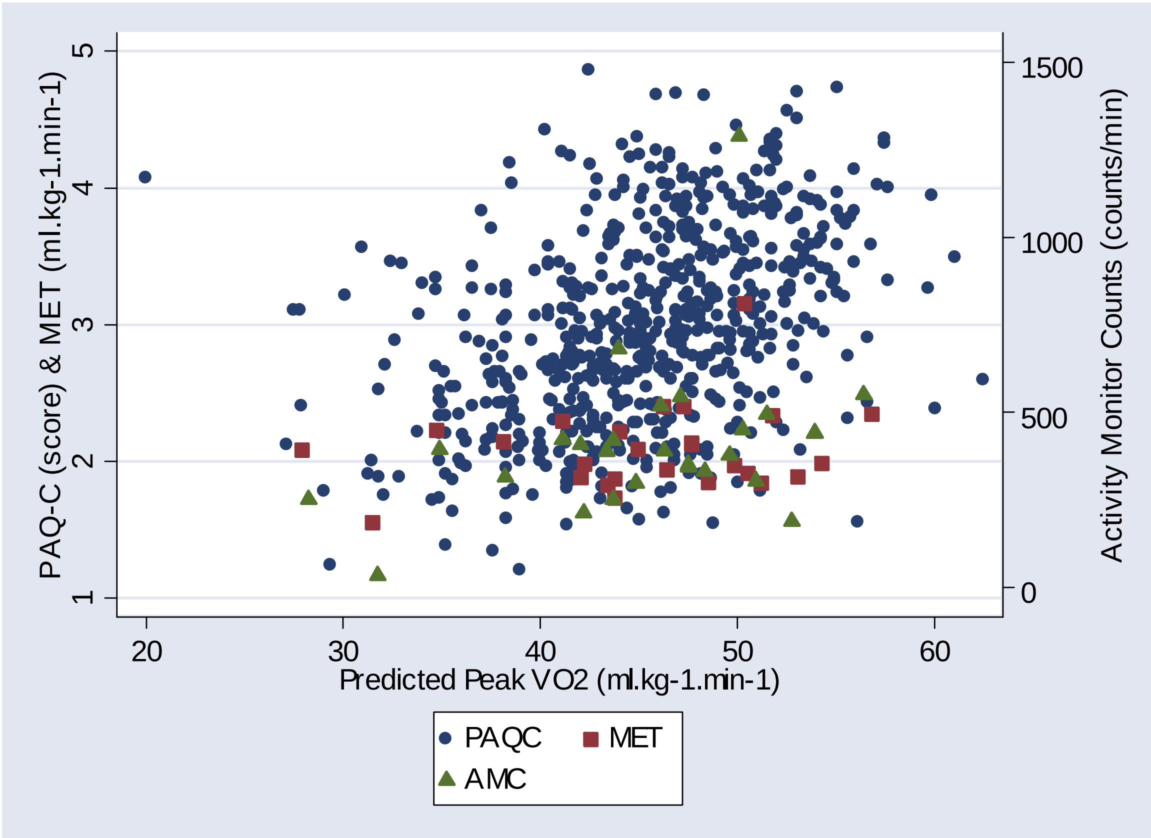



**Figure 3.8 Scatterplots of predicted peak $\dot{V}O_2$ and measures of physical activity**

Scatterplots demonstrate a positive relationship between predicted peak $\dot{V}O_2$ and PAQ-C in a total of 635 non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years. Scatterplots also demonstrate a lack of relationship between predicted peak $\dot{V}O_2$ and activity monitor counts, and between predicted peak $\dot{V}O_2$ and MET in 26 non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years. AMC = Activity monitor counts; MET = metabolic equivalent; PAQ-C = Physical Activity Questionnaire for Children.

Regression analysis equations:

Predicted peak $\dot{V}O_2$ = 0.01 (Activity Monitor Counts) + 40.8 ($R^2$=0.13; p=0.07)

Predicted peak $\dot{V}O_2$ = 3.43 (PAQ-C) + 35.0 ($R^2$=0.17; p<0.0001)

Predicted peak $\dot{V}O_2$ = 4.81 (Estimated MET) +35.2 ($R^2$=0.05; p=0.27)

### 3.3.9 Relationship between Physical Activity and Body Composition

#### 3.3.9.1 PAQ-C and BMI

Mean PAQ-C values, categorised by gender- and age-specific BMI cutoff points (Cole *et al.*, 2000), are shown in Table 3.17 and regression analysis findings are displayed in Table 3.18. There were no significant differences in mean PAQ-C according to BMI classification, and regression analysis demonstrated no significant associations for any grade or gender group. However, a significant inverse association ($R^2$=0.04; p=0.01) was observed for the combined data set (n=635). An illustration of PAQ-C versus BMI is shown in Figure 3.9. The low number of participants classified as obese resulted in overweight- and obese-classified participants being analysed as a single group.

**Table 3.17 PAQ-C stratified according to the BMI categories of Cole *et al*. (2000)**

| **Group** | **PAQ-C Normal BMI** | **PAQ-C Overweight/Obese BMI** |
|---|---|---|
| **Grade 5 Males** | 3.38 ± 0.65 (n=141) | 3.43 ± 0.70 (n=40) |
| **Grade 5 Females** | 3.05 ± 0.70 (n=127) | 3.00 ± 0.45 (n=20) |
| **Grade 8 Males** | 3.00 ± 0.64 (n=103) | 2.82 ± 0.60 (n=30) |
| **Grade 8 Females** | 2.51 ± 0.62 (n=129) | 2.40 ± 0.40 (n=45) |

Mean ± SD

**Table 3.18 Regression analysis for PAQ-C and BMI**

| Group | PAQ-C = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males** | -0.012 (BMI) + 3.62 | 0.003 | 0.44 |
| **Grade 5 Females** | -0.0004 (BMI) + 3.05 | 0.007 | 0.99 |
| **Grade 8 Males** | -0.016 (BMI) + 3.30 | 0.007 | 0.33 |
| **Grade 8 Females** | -0.007 (BMI) + 2.63 | 0.002 | 0.55 |

### 3.3.9.2 PAQ-C categorised by %BF

Mean PAQ-C values, stratified according to age- and gender-specific %BF cutoff points (Taylor *et al.*, 2002), are shown in Table 3.19 and regression analysis results are displayed in Table 3.20. No differences were observed in mean PAQ-C according to %BF classification, and regression analysis demonstrated no significant associations for any grade or gender group. However, a significant inverse association ($R^2$=0.08; p=0.01) was observed for the combined data set (n=635). An illustration of PAQ-C versus %BF is shown in Figure 3.9. The low number of participants classified as obese resulted in overweight- and obese-classified participants being analysed as a single group.

**Table 3.19 PAQ-C as categorised by %BF strata of Taylor *et al*. (2002)**

| Group | PAQ-C<br>Normal %BF | PAQ-C<br>Overweight/Obese %BF |
|---|---|---|
| **Grade 5 Males** | 3.40 ± 0.62<br>(n=100) | 3.40 ± 0.70<br>(n=81) |
| **Grade 5 Females** | 3.04 ± 0.70<br>(n=104) | 3.04 ± 0.60<br>(n=43) |
| **Grade 8 Males** | 3.03 ± 0.63<br>(n=84) | 2.90 ± 0.63<br>(n=49) |
| **Grade 8 Females** | 2.53 ± 0.60<br>(n=136) | 2.32 ± 0.45<br>(n=38) |

Mean ± SD

**Table 3.20 Regression analysis for PAQ-C and %BF**

| Group | PAQ-C = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males** | -0.006 (%BF) + 3.53 | 0.003 | 0.50 |
| **Grade 5 Females** | 0.004 (%BF) + 2.92 | 0.001 | 0.73 |
| **Grade 8 Males** | -0.013 (%BF) + 3.24 | 0.01 | 0.18 |
| **Grade 8 Females** | -0.017 (%BF) + 3.00 | 0.02 | 0.10 |

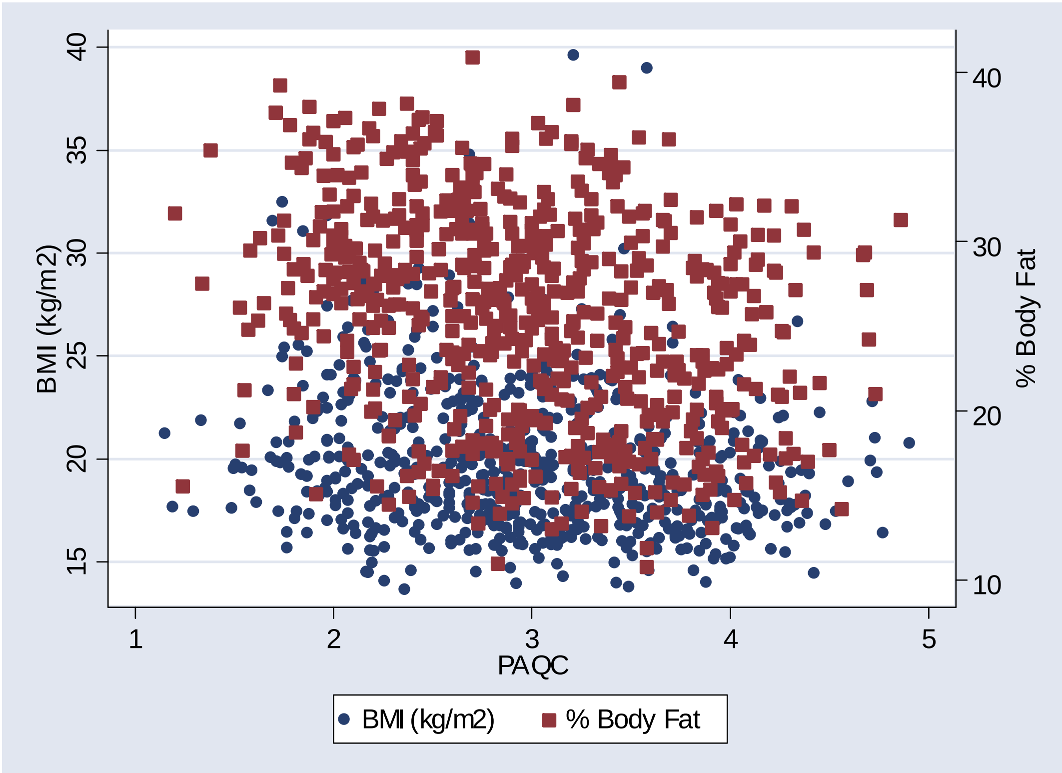



**Figure 3.9 Scatterplots of BMI and % Body Fat versus PAQ-C**

Scatterplots demonstrate significant inverse relationships between PAQ-C and BMI, and between PAQ-C and %BF in 635 non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years. BMI = Body mass index; PAQ-C = Physical Activity Questionnaire for Children.

Regression analysis equations for the combined data set (n=635):

PAQ-C = -0.04 (BMI) + 3.75 ($R^2$=0.04; p=0.01)

PAQ-C = -0.03 (%BF) +3.81 ($R^2$=0.08; p=0.01)

### 3.3.9.3 Activity monitor counts and body composition - BMI and %BF

Correlation analysis results for the relationships between activity monitor counts and the two body composition measures, BMI and %BF, are shown in Table 3.21. No relationships were found between activity monitor counts and BMI or between activity monitor counts and %BF. Due to the small sample size, grades were not subdivided into BMI or %BF categories as outlined by Cole *et al.* (2000) and Taylor *et al.* (2002). The association between activity monitor counts and BMI and %BF is shown in Figure 3.10.

**Table 3.21 Correlation analysis for BMI and %BF versus activity monitor counts**

| Group | Variable | Pearson's r | p |
|---|---|---|---|
| **Grade 5 Males (n=6)** | **BMI** | 0.49 | 0.32 |
| | **%BF** | 0.31 | 0.54 |
| **Grade 5 Females (n=8)** | **BMI** | -0.60 | 0.12 |
| | **%BF** | -0.63 | 0.10 |
| **Grade 8 Males (n=6)** | **BMI** | 0.49 | 0.33 |
| | **%BF** | 0.56 | 0.24 |
| **Grade 8 Females (n=6)** | **BMI** | -0.80 | 0.06 |
| | **%BF** | -0.63 | 0.18 |


**Figure 3.10 Scatterplots of BMI and % Body Fat versus Activity Monitor Counts**

Scatterplots demonstrate the associations between BMI and activity monitor counts, and between %BF and activity monitor counts in 26 non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years. BMI = Body mass index.

Regression analysis equations:

Activity monitor counts = -9.8 (BMI) + 618.3 ($R^2$=0.03; p=0.43)

Activity monitor counts = -7.3 (%BF) + 609.5 ($R^2$=0.05; p=0.25)

### 3.3.9.4 Estimated MET and body composition – BMI and %BF

Correlation analysis results for the relationships between estimated MET and BMI, and between estimated MET and %BF, are shown in Table 3.22. The only significant relationship was an inverse association between estimated MET and BMI in Grade 8 females. No other significant results were found. The associations between estimated MET, BMI and %BF are shown in Figure 3.11.

**Table 3.22 Correlation analysis for BMI and %BF versus estimated MET**

| Group | Variable | Pearson's r | P |
|---|---|---|---|
| **Grade 5 Males (n=6)** | **BMI** | 0.51 | 0.31 |
| | **%BF** | 0.33 | 0.52 |
| **Grade 5 Females (n=8)** | **BMI** | -0.51 | 0.19 |
| | **%BF** | -0.60 | 0.11 |
| **Grade 8 Males (n=6)** | **BMI** | 0.44 | 0.39 |
| | **%BF** | 0.59 | 0.22 |
| **Grade 8 Females (n=6)** | **BMI** | -0.88 | 0.01 |
| | **%BF** | -0.73 | 0.10 |

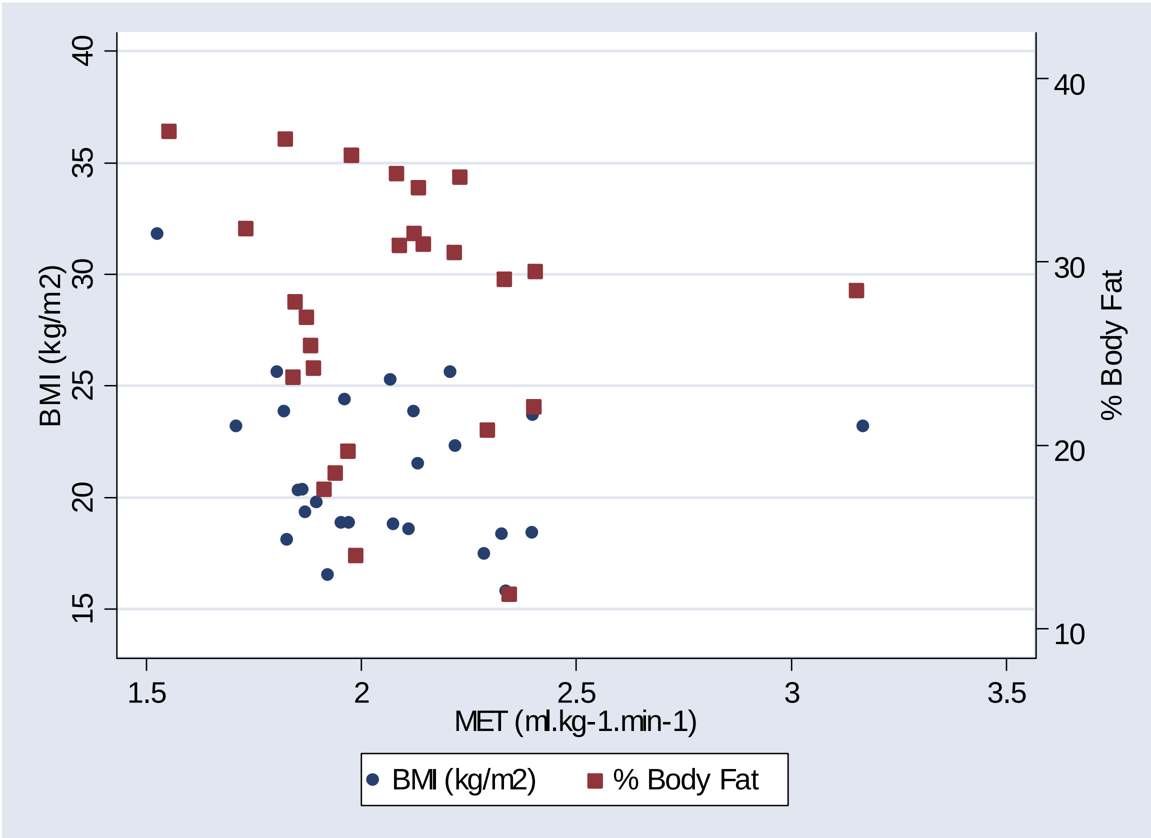



**Figure 3.11 Scatterplots of estimated MET versus BMI and % Body Fat**

Scatterplots demonstrate the associations between BMI and estimated MET, and between %BF and estimated MET, in 26 non-asthmatic grade 5 children and grade 8 adolescents aged 10-14 years.

BMI = Body mass index; MET = metabolic equivalent.

Regression analysis equations:

MET = -0.02 (BMI) + 2.45 ($R^2$=0.04; p=0.32)

MET = -0.01 (%BF) + 2.21 ($R^2$=0.01; p=0.61)

### 3.3.10 Relationship between Physical Activity, Aerobic Fitness and Body Composition

**Participants (n=635) as a single group**

Pearson correlation coefficients for the linear associations between BMI, %BF, 6MRD, 6MRD/FFM, PAQ-C, activity monitor counts, and estimated MET for all participants are shown in Table 3.23.

- BMI was significantly positively associated with %BF and significantly inversely associated with 6MRD, 6MRD/FFM and PAQ-C.
- %BF was significantly inversely associated with 6MRD, 6MRD/FFM and PAQ-C.
- 6MRD was significantly positively associated with 6MRD/FFM and PAQ-C.
- 6MRD/FFM was significantly positively associated with PAQ-C.
- Activity monitor counts were significantly and positively correlated with PAQ-C and estimated MET.

**Table 3.23 Correlation coefficients between measures of body composition, aerobic fitness and daily physical activity**

| Group | BMI | %BF | 6MRD | 6MRD/FFM | PAQ-C | Activity Monitor Counts | MET |
|---|---|---|---|---|---|---|---|
| **BMI** | 1.00 | | | | | | |
| **%BF** | 0.69* | 1.00 | | | | | |
| **6MRD** | -0.36* | -0.59* | 1.00 | | | | |
| **6MRD/ FFM** | -0.75* | -0.54* | 0.57* | 1.00 | | | |
| **PAQ-C** | -0.19[a] | -0.29[a] | 0.34* | 0.36* | 1.00 | | |
| **Activity Monitor Counts** | -0.16 | -0.23 | 0.33 | 0.21 | 0.38[a] | 1.00 | |
| **MET** | -0.20 | -0.11 | 0.10 | 0.27 | 0.38 | 0.85* | 1.00 |

Analysis includes all non-asthmatic participants (n=635)

* significant at $p<0.0001$ level

[a] significant at $p<0.05$ level

## 3.4 Discussion

Overweight and obesity prevalence in childhood and adolescence has risen dramatically over recent decades (Magarey *et al.*, 2001). One of the primary suggestions for this increase is a reduction in habitual physical activity. An elevated adiposity and/or a decreased involvement in habitual physical activity raises concerns about possible detrimental effects on cardiorespiratory fitness as well as on cardiovascular health. However, a limited evidence base exists that addresses the inter-relationships between adiposity, physical activity and aerobic fitness in a paediatric population.

The results of the current study confirm that overweight and obesity is a significant problem in children and adolescents, aged 10 to 14 years, from a sample of primary and secondary schools in Melbourne, Australia. This is demonstrated by the body composition measures, in which overweight/obesity prevalence rates were 21.1% and 33.3% when assessed by BMI and %BF measures, respectively. The BMI data support recent data for children from an Australian sample in which overweight and obesity was reported to be 19.7% and 4.8%, respectively (Hesketh *et al.*, 2004), and between 19 and 23% in total (Booth *et al.*, 2001), when classified by BMI. In addition, the current average %BF values for grade 5 participants are also in keeping with recently published Australian data for boys and girls aged 8.4 ± 0.9 years which reported mean %BF values of 25.2 ± 7.8% and 32.2 ± 6.2%, respectively (Abbott & Davies, 2004).

The most important outcome was a significant inverse association between measures of aerobic fitness and body composition. Each group of school grade and gender, demonstrated significant inverse associations between 6MRD and predicted peak $\dot{V}O_2$ versus the two measures of body composition (BMI and %BF) (see Tables 3.9 & 3.12 in Appendix L: Chapter 3 Appendices, Figures 3.6 & 3.7). In an attempt to examine more clearly the extent to which body composition determined aerobic fitness, the findings were examined with children stratified according to gender- and age-specific BMI (Cole *et al.*, 2000) and %BF (Taylor *et al.*, 2002) categories.

The grouping of participants into the standard BMI categories (Cole *et al.*, 2000) demonstrated that overweight and obese children had lower aerobic fitness outcomes (6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$) when compared to *normal* weight-for-age children (see Table 3.8). This decrement in aerobic fitness was most pronounced in the children categorised as obese (see Figure 3.6). Similarly, when participants were stratified according to %BF categories (Taylor *et al.*, 2002), children in the *normal* %BF group demonstrated significantly greater aerobic fitness outcomes compared to those in the overweight/obese group (see Table 3.11). However, it should be noted that field-based running tests may underestimate the aerobic power of overweight/obese individuals.

It is generally accepted that overweight and obese children and adolescents display lower aerobic fitness scores when compared to *normal weight* children in laboratory-based running tests (Armstrong *et al.*, 1991; Rowland, 1991) when aerobic fitness is reported as $ml.min^{-1}$ per kilogram body weight. However, when aerobic fitness is expressed in terms of FFM, some studies suggest that these differences in aerobic fitness disappear (Elliot *et al.*, 1989; Maffeis *et al.*, 1994). The findings of this study do not support these reports. In fact, lower aerobic fitness outcomes remained for overweight and obese participants even after data were expressed relative to FFM. These results are in agreement with Davies *et al.* (1975) who reported significantly lower (16.3%) FFM-corrected aerobic fitness values for obese females against those of non-obese females. Furthermore, Nassis *et al.* (2005) more recently reported that BMI and %BF values were significantly lower in overweight and obese children with a higher level of aerobic fitness in comparison to children in the same BMI category with a lower level of aerobic fitness.

The poorer 6MRD performance observed for overweight/obese participants cannot be explained by a depressed cardiovascular function alluded to in an adult overweight/obese population (Gustafson *et al.*, 1990), where decreased maximal heart rates during exercise were reported, with diminished maximal catecholamine responses suggested as the cause. In the current study, peak heart rate values were not significantly different when comparing groups categorised by BMI or %BF (see Tables 3.8 & 3.11).

A primary determinant which may explain the inverse association between aerobic fitness and body composition is a decreased involvement in physical activity. However, despite there being weak significant inverse associations ($R^2$=0.04-0.08) between PAQ-C and measures of body composition when analysis was performed using the combined (n=635) data set (see Table 3.23), no associations or differences in PAQ-C according to BMI and %BF category were identified for each grade and gender group analysis (see Tables 3.17, 3.18, 3.19, 3.20 & Figure 3.9). Therefore, the PAQ-C findings are either not sensitive enough or do not support the notion that a lower level of physical activity is the major factor contributing to the poorer aerobic fitness displayed by the overweight and obese participants. These findings are supported by a review by Bar-Or and Baranowski (1994) which focused on physical activity in obese adolescents. In a review of 13 studies, no consistent or convincing relationship between physical activity and body composition could be found. In fact, only five studies demonstrated significant relationships. However, it should be noted that the five studies typically had larger participant numbers than studies failing to observe any significant association between physical activity and body fat. In a review by Ward and Evans (1995), the number of studies supporting an inverse relationship between body fat and physical activity were similar to the number of studies reporting no association. The authors of both reviews highlighted methodological inadequacies that most likely contributed to the equivocal nature of the literature.

Given that the PAQ-C is a seven-day recall, self-report measure of physical activity and, as such, subjective in nature, an objective measure of physical activity was sought (Sirard & Pate, 2001). Therefore, a subgroup of 26 participants (11 of whom were overweight or obese) wore an activity monitor for seven consecutive days. However, total daily activity monitor counts (a measure of physical activity volume) again failed to show any consistent significant associations with body composition (see Tables 3.21). Moreover, estimated MET values were not consistently associated with measures of body composition either (see Tables 3.21 & 3.22, and Figures 3.10 & 3.11). A retrospective analysis was performed to ascertain the minimum sample size required to detect a significant difference between groups with 80% power – this produced an *n* of 691. A sample size of this magnitude was beyond the resources of this study and, as such, the sample size of 26 may have contributed to the lack of any relationship. Intuitively, it is reasonable to suggest that tri-axial accelerometers would better capture children's activity and, therefore, may have revealed an association between activity monitor counts and body composition. However, no direct evidence exists to suggest superiority of any one type of monitor (Welk *et al.*, 2000). In addition, another consideration is the epoch length used. It has previously been suggested that a 60-second epoch may obscure the short bursts of moderate to vigorous physical activity typically exhibited by children (Bailey et al., 1995). Hence, the current study may have also benefited from employing a shorter epoch.

The volume of physical activity (i.e. total daily activity monitor counts) alone is not the only component in the overall physical activity profile. The intensity of physical activity must also be considered. Indeed, time spent performing vigorous activity has been reported to be inversely associated with body fat in children (Abbott & Davies, 2004), while Ekelund *et al.* (2002) reported that the duration and intensity of physical activity was significantly lower in obese adolescents. The activity monitor does provide an estimate of physical activity intensity when the data are expressed as the number of counts per minute. The categorisation of activity monitor counts data according to age-specific intensity levels (Trost, 2001) showed no differences between BMI-classified *normal weight* and overweight/obese participants for the time spent in each intensity range (see Table 3.6b). This again suggests that differences in physical activity are not responsible for the lowered aerobic fitness in the overweight/obese participants.

Body mass and its impact on the metabolic economy of movement may result in heavier children expending more energy when moving at the same speed as peers of lesser body mass (Schutz *et al.*, 2001). This point has been raised previously in a review by Bar-Or and Baranowski (1994) in which it was concluded that the absolute total energy expenditure of obese adolescents may be equal or even greater than non-obese adolescents. This concept that has since been supported elsewhere (Ekelund *et al.*, 2002; Lazzer *et al.*, 2003).

In an attempt to gain insight into this issue, estimates of energy expenditure were derived from 6MRD values (see Section 2.2.8, page 116). Despite running less distance in six minutes, it was estimated that the overweight/obese participants actually expended more energy compared to their *normal weight* counterparts (see Table 3.10). This agrees with previous reports of obese children having comparable or greater aerobic fitness than non-obese children when expressed in absolute terms ($L.min^{-1}$) (Davies *et al.*, 1975; Elliot *et al.*, 1989; Rowland, 1991; Maffeis *et al.*, 1994). Greater energy expenditure in overweight/obese children may be particularly pertinent when considering that obese children typically have a greater FFM compared to non-obese children, as reported here and in other studies (Davies *et al.*, 1975; Rowland, 1991; Maffeis *et al.*, 1994). The impact of an excess load carriage on energy expenditure is further highlighted by Maffeis *et al.* (1994), who showed that obese children had a significantly greater absolute $\dot{V}O_{2max}$ than *normal weight* controls when tested on a treadmill, yet had comparable results when tested on a cycle ergometer on which body mass is supported.

Therefore, when PAQ-C, activity monitor counts, and energy expenditure data are considered together, a lack of involvement in physical activity is not significantly linked to excess body mass or lower aerobic fitness levels observed in the overweight/obese children and adolescents of this study. In the present study, it appears that the lower 6MRD (resulting in lower predicted peak $\dot{V}O_2$) of the overweight/obese participants may be the result of a greater energy expenditure for a given work rate. Therefore, excess fatness may not actually reduce the ability to maximally consume oxygen, but simply reduce locomotive functional capacity. The studies of Davies *et al*. (1975), Elliot *et al*. (1989), Maffeis *et al*. (1994) and Rowland (1991) collectively support this concept. However, overweight/obese participants did demonstrate lower 6MRD/FFM values when compared to their normal weight peers and, hence, an added limitation may still be present with respect to the maximal consumption of oxygen.

The distance of the activity monitor from the centre of gravity is reported to influence the acceleration signal. That is, even when the same positioning strategy is used (i.e. on the hip), the acceleration signal is greater when the activity monitor is further from the centre of gravity, as is the case with heavier children when compared with their lighter peers (Westerterp, 1999). Additionally, the sensitivity of the acceleration signal is also influenced by the interplay of stride length and step frequency. Specifically, at the same speed of movement, the acceleration signal is lower when the step frequency is higher (typical of smaller, lighter children and adolescents) (Brage *et al.*, 2003). For these reasons, comparable activity monitor counts between body composition strata may not necessarily equate to comparable involvement in physical activity. Moreover, accelerometers may under-estimate energy expenditure at low-intensity and over-estimate energy expenditure during high-intensity activity (Schmitz et al., 2005). This suggests that the cut-off points employed for defining intensity in this study may have also been a limiting factor. Hence, although the current data does not support the premise, it remains feasible that overweight/obese participants may have engaged in less physical activity than their lighter weight peers.

Analysis incorporating grade and gender groups demonstrated significant positive associations between PAQ-C and the three measures of aerobic fitness (except for the grade 5 female relationship between PAQ-C and 6MRD/FFM, which failed narrowly to reach significance, see Table 3.13). However, $R^2$ values for these associations were weak, ranging from 0.02 to 0.11. No significant associations were found for the relationship between activity monitor counts and aerobic fitness. A review by Morrow and Freedson (1994) focusing on the relationship between physical activity and aerobic fitness among adolescents supports the outcomes of this study. In their review, they reported that 50% of studies described a small to moderately significant relationship between physical activity and aerobic fitness, with a median r = 0.17 ($R^2 < 0.03$). Importantly, it should be noted that in this review, all studies with a sample size of 186 or larger detected a significant relationship between activity and fitness. However, most studies did not make adjustments for age and gender. Variability in the methods between these studies may partly explain the poor overall relationship. Nevertheless, of interest is a study which evaluated the impact of nine weeks of bed rest on the peak $\dot{V}O_2$ values of five children aged 7 to 11 years (Rowland, 1994). It was estimated that children only lost 13% of their peak $\dot{V}O_2$ throughout this period of inactivity, indicating that the contribution of physical activity upon aerobic fitness may be minimal (Rowland, 1994).

## Normative Data

### *Body Composition*

Grade 8 males and females recorded significantly greater mean BMI values when compared with grade 5 males and females. Given the normal age associated increases in body mass that accompany somatic growth (Malina *et al.*, 2004), the current findings are consistent with expected trends.

Males had significantly lower %BF when compared to females of the same age, while grade 5 females had significantly lower %BF compared to grade 8 females. The accumulation of body fat among females during adolescence (Malina *et al.*, 1988; Guo *et al.*, 1992) is likely to explain the differences between grade 8 males and females, and between grade 5 and 8 females. With respect to grade 5 participants, several studies using dual energy X-ray absorptiometry in children have shown differences in fat mass between pre-pubertal boys and girls (Boot *et al.*, 1997; Nagy *et al.*, 1997; Taylor *et al.*, 1997; Mast *et al.*, 1998). Although no measurements of pubertal stage were collected in the current study, the differences in %BF between grade 5 males and females echo the findings of the studies mentioned. Gender differences in %BF were independent of body mass, due to an absence of differences in body mass between genders of the same age (see Table 3.1).

Daniels *et al.* (1997) reported that BMI may under-represent %BF in children and adolescents who have a greater central adiposity distribution. If an under representation of overweight and obesity occurred in the reported BMI in present study, this may explain the discrepancy seen in the reported prevalence of overweight and obesity as measured by BMI (21.1%) and %BF (33.3%) in this study.

Given the large size of the current sample, the collection of data from various regions of metropolitan Melbourne, and the consistencies with the established literature, the results of this study likely represent real phenomena and are characteristic of the wider population in terms of body composition as assessed by BMI and %BF. These results also bring to light the underlying effects that maturation may have caused among participants. Ideally, pubertal staging would have been included in our study protocol, however, such testing in a large field based setting was deemed to be a difficult environment in which to guarantee the confidentiality of participants returning the self-report form and was therefore not employed.

***Aerobic Fitness***

Males recorded greater 6MRD values (and predicted peak $\dot{V}O_2$ values) when compared to females of the same age. It is unlikely that a lack of motivation among females is responsible for these results because of the absence of differences in peak heart rate between genders (see Table 3.4). In addition, the greater levels of haemoglobin reported for adolescent males only manifest towards the end of male puberty (Dallman & Siimes, 1979), and hence, haemoglobin counts between genders seem unlikely to explain the aerobic fitness differences. However, the greater muscle mass observed for males in both grade levels (see Table 3.1), and hence the greater degree of force producing tissue, may greatly explain the differences observed between genders.

The current results are in agreement with the available literature. Aerobic power relative to body mass remains stable among males between the ages of 6 to 16, whilst for females, it declines at around 2% per annum (Sallis, 1993; Armstrong & Welsman, 1996). Typical mass-related peak $\dot{V}O_2$ values in boys across the adolescent period remain around 49.0–50.0 $ml.kg^{-1}.min^{-1}$, while, in contrast, there is a marked tendency for mass-related peak $\dot{V}O_2$ in adolescent females to decline from 45.0 to 39.0 $ml.kg^{-1}.min^{-1}$ through adolescence (Åstrand, 1952; Åstrand, 1956; Daniels & Oldridge, 1971; Cunningham *et al.*, 1984; Cunningham *et al.*, 1984).

Grade 8 males ran significantly further than grade 5 males however, given that younger children have smaller heart sizes, blood volume, and stroke volume compared with older children (Turley & Wilmore, 1997), and that older children have increased muscle mass, limb and stride length (Bar-Or, 1989), the greater running performance in the older age group was not unexpected.

Grade 5 females achieved significantly greater predicted peak $\dot{V}O_2$ values compared with grade 8 females, which may be partly due to the accumulation of body fat during puberty (Malina *et al.*, 1988; Guo *et al.*, 1992) and, hence, a greater degree of non-force producing tissue mass. This reasoning may also help to explain the significantly greater 6MRD/FFM values of grade 5 participants compared with those of the grade 8 group. Furthermore, the significantly greater 6MRD/FFM values of grade 8 males compared to females of the same age may also be substantially explained by the increase in body fat throughout puberty which is more pronounced in females.

The results of the current sample compare favourably with 6MR distances reported in other studies from Australia. A study of 59 school girls (aged 10 to 14 years) from Melbourne reported mean 6MRD of 1021 ± 128.5 m and 1046.5 ± 128.6 m for grade 5 and 8 girls, respectively (Bate, 2001). In a comparable study of 57 school boys (aged 10 to 14 years) from Melbourne, mean 6MRD values of 1066.6 ± 148.1 m and 1276.5 ± 69.8 m were reported for grade 5 and 8 boys, respectively (Toohey, 2000). Furthermore, peak $\dot{V}O_2$ values from several studies of similarly aged children and adolescents show strong agreement with the results of the current study (see Table 3.24). It should be acknowledged that, although the 6MRT was always performed in dry conditions, seasonal variation may have influenced the results. Specifically, environmental factors such as temperature, wind strength and humidity may have affected the performance ability, and indeed the motivation levels of some participants. Moreover, the 6MRT requires participants to pace themselves, a task which may have been difficult for some.

**Table 3.24 Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$) values attained via indirect calorimetry in studies of children and adolescents**

| **Boys Peak $\dot{V}O_2$ (age)** | **Girls Peak $\dot{V}O_2$ (age)** | **N** | **Ergometer** | **Reference** |
|---|---|---|---|---|
| 47.3 ± 5.6*<br>(10.90 ± 0.50 years)<br>47.1 ± 6.2*<br>(13.52 ± 0.40 years) | 45.0 ± 5.0*<br>(10.90 ± 0.41 years)<br>41.7 ± 4.8*<br>(13.80 ± 0.50 years) | 314 M, 321 F | - | CURRENT STUDY |
| 42.0 ± 6.0<br>(≤13.0 years)<br>50.0 ± 8.0<br>(>13.0 years) | 38.0 ± 7.0<br>(≤ 11.0 years)<br>34.0 ± 4.0<br>(> 11.0 years) | 58 M, 51 F | Cycle | (Cooper & Weiler-Ravell, 1984) |
| 51.0 ± 6.0<br>(11.1 years) | 45.0 ± 5.0<br>(10.9 years) | 111 M, 53 F | Treadmill | (Armstrong *et al.*, 1995) |
| 49.3 ± 7.1<br>(11.2 years) | 42.7 ± 7.3<br>(11.2 years) | 119 M, 115 F | Treadmill | (Armstrong *et al.*, 1999) |
| 46.1 ± 5.8<br>(10.9-12.8 years) | 43.1 ± 5.6<br>(10.9-12.8 years) | 13 M, 24 F | Treadmill | (Rowland & Boyajian, 1995) |
| | 40.0<br>(11.7 years) | 24 F | Cycle | (Rowland *et al.*, 2000) |

Mean ± SD, M = Male, F = Female, * Peak $\dot{V}O_2$ estimated from six minute running distance

***Physical Activity***

Males recorded greater PAQ-C values when compared to females, and grade 8 males recorded a greater mean estimated MET value in comparison to grade 8 females. These results may be explained, at least partially, by a more pronounced accumulation of body fat throughout puberty in females (Malina *et al.*, 1988; Guo *et al.*, 1992) and a greater energy expenditure for a given activity among individuals with elevated fat levels (Ekelund *et al.*, 2002). In addition, it has been suggested that boys may have a preference for more vigorous activities than girls throughout youth (van Mechelen *et al.*, 2000; Hussey *et al.*, 2001), a concept supported by the findings that grade 5 males spent less time engaging in light intensity activities and more time in extreme intensity activities when compared to females of the same age (see Table 3.6a). The idea that boys have a greater propensity for vigorous physical activities compared to girls is also supported by reports that the gender difference in physical activity is greatly reduced when moderate activity alone is compared (Riddoch & Boreham, 1995; van Mechelen *et al.*, 2000; Trost *et al.*, 2002). Moreover, social-cognitive determinants of activity behaviour have also been suggested to explain the gender difference in physical activity (Trost *et al.*, 1996). Specifically, Trost *et al.* (1996) reported that boys were more confident in their ability to overcome traditional barriers to physical activity including time constraints, feelings of fatigue, poor weather, and homework obligations. Further factors proposed to influence the gender disparity in physical activity include differences in motor skill development (Thomas & French, 1985), parental beliefs (Perusse *et al.*, 1989; Brustad, 1996), and socialization of the family unit (Herkowitz, 1980; Butcher, 1983; Stucky-Ropp & DiLorenzo, 1993; Trost *et al.*, 1996). Moreover, when surveyed, both boys and girls have reported boys as having a lower likelihood of injury than girls for the same given activity (Morrongiello *et al.*, 2000).

Grade 5 children had significantly greater PAQ-C and estimated MET values when compared to grade 8 participants, which is consistent with the well-established trend of decreasing physical activity with age (Sallis, 1993; Crocker *et al.*, 1997). Much of this decline may be attributed to a decrease in participation in non-organised sport (van Mechelen *et al.*, 2000).

Results from the PAQ-C in the present study are in agreement with existing literature. A Canadian study of 466 children aged 10 to 14 years found boys (3.21 ± 0.67) to provide greater PAQ-C scores compared with girls (2.95 ± 0.64) (Crocker *et al.*, 2000). In addition, a study of 215 children and adolescents aged 9 to 15 years reported children aged 12 years or less had greater PAQ-C scores when compared with participants aged 13 years or older (Crocker *et al.*, 1997). Crocker *et al.* (1997) reported mean PAQ-C scores similar to those seen in the current study of 3.44 ± 0.68 and 2.96 ± 0.69 for males and females, respectively. Moreover, 43 non-asthmatic Melbourne females in grade 5 and 8 recorded mean PAQ-C values of 2.90 ± 0.11 and 2.34 ± 0.13, respectively (Bate, 2001), while a study of 30 non-asthmatic Melbourne males in grade 5 and 8 were observed to have mean PAQ-C values of 3.20 ± 0.15 and 3.00 ± 0.15, respectively (Toohey, 2000).

A study of 35 Melbourne school girls aged 10 to 14 years who wore an activity monitor, was comparable to the activity monitor counts of the current sample, with 325.6 ± 182.3

counts/min and 281.4 ± 112.4 counts/min reported for grade 5 and 8 girls, respectively (Bate, 2001). However, in comparison with children from other countries (Brage *et al.*, 2004; Jago *et al.*, 2004), the activity monitor counts in the present study are low. Jago *et al.* (2004) reported mean activity monitor counts of 509.1 ± 144.4 counts/min in a study of 8- to 10-year-old African-American girls, while Brage *et al.* (2004) reported a mean value of 660 ± 233 in a study of 589 Danish children, also aged 8 to 10 years. Notably, however, Brage *et al.* (2004) and Jago *et al.* (2004) both only monitored children for approximately three days. The duration of monitoring may have included typically high weekend activity levels, but this is not reported. Brage *et al.* (2004) also removed from their analysis any periods of 10 minutes or greater where there was no activity. Furthermore, Brage *et al.* (2004) collected over a daily period of approximately 10 hours, whereas the current study analysed data over an approximate 16-hour daily period. In addition, overweight/obesity prevalence rates of 9.8% and 12.2% for 13-year old Danish boys and girls, respectively (Lissau *et al.*, 2004), are considerably lower than the rates observed for similarly aged participants in this study, suggesting Danish youth may be more active. All these factors act in favour of greater mean activity counts per minute in the other studies.

A number of limitations should be considered when analysing PAQ-C and activity monitor data. Firstly, Crocker *et al.* (1997) emphasised that the PAQ-C design may result in a bias toward younger people. Specifically, a number of questions are focused on physical activity performed at school. However, some evidence suggests older children to be more active outside school settings (Miller *et al.*, 1994). Therefore, the questions of the PAQ-C may be intrinsically biased towards lower scores in older participants. Furthermore, young people have shown difficulty in accurately recalling their physical activity habits (Baranowski & Simons-Morton, 1991; Sallis *et al.*, 1996).

The uni-axial activity monitor used in the current study has several inherent limitations. In addition to the limitations described earlier, swimming, a popular activity in Australia, is an activity that cannot be assessed via the activity monitor. Compounding this issue, participants did not complete an activity diary while wearing the activity monitor, and therefore, the contribution of swimming to the physical activity profile cannot be quantified. Moreover, although vertical acceleration can be measured accurately, external work performed in activities such as cycling, rowing, climbing or weight lifting are not accurately reflected (Puyau *et al.*, 2002). Cycling is also a popular means of active transport and a common pastime among young people in Australia and, as such, accelerations from this pursuit may not have been accurately captured. Furthermore, motion sensors worn on the hip are unable to discriminate between changes in terrain such as walking on flat ground versus walking up a flight of stairs (Strath et al., 2001). Additionally, the activity monitor is designed to be worn vertically on the hip with the cantilever at an angle of 90º. Although the activity monitor was correctly fitted on the first day of monitoring, parent or self-fitting was performed for the remainder of monitoring and the angle of the cantilever could not be assured. Given that a 15º shift can reduce activity monitor count scores by 6% (Metcalf *et al.*, 2002), this may play a part in the overall lower activity monitor values compared to other studies (Brage *et al*., 2004; Jago *et al*., 2004). Moreover, the conversion of activity monitor counts to MET using the equation of Freedson et al. (1997) may have been affected by the 60-second epoch. Specifically, a shorter epoch may have better captured the short bursts of moderate to vigorous activity typically observed in children. Finally, the sample size of participants wearing the activity monitor may not have been large enough to detect any significant relationships that may in fact exist.

Despite the intention for for activity monitor counts and PAQ-C to measure the same variable, no significant associations were found between their results. Similarly-aged Melbourne school girls (Bate, 2001) and children with cystic fibrosis (Kelly, 2002) also failed to establish a significant association between activity monitor counts and PAQ-C data. The difficulty with grade 5 children trying to accurately recall physical activity duration times (Baranowski & Simons-Morton, 1991; Sallis *et al.*, 1996), the errors and possible under- and over-estimations of the activity monitor (Metcalf *et al.*, 2002) and the low sample size of this study may all have partly contributed to the lack of significant association reported between activity monitor counts and PAQ-C.

It should also be noted that the amount of time participants spent in vigorous and extreme physical activity intensity ranges (up to 10% of the day) is an unprecedented finding. A study of similarly aged children showed that vigorous activity in play accounted for only 3% of the daily total (Bailey et al., 1995). It is therefore acknowledged that there may have been a fault with the accelerometers used or perhaps the download software.

## Concluding Remarks

Overall, the current sample appears to be representative of similarly-aged children and adolescents within Australia in terms of overweight/obesity prevalence. Disturbingly, 21.2% of participants were found to be either overweight or obese when classified by BMI. In addition, a significant inverse relationship was observed between aerobic fitness and markers of increased body fat, even after corrections to aerobic fitness were made for fat free mass. This association could be only partially explained by differences in daily physical activity. In fact, the current findings suggest that decreased levels of daily physical activity are not associated with the increased overweight/obesity prevalence among this sample, and that physical activity lacks a strong link to paediatric overweight/obesity in this population. These findings are clinically significant and highlight the association between aerobic fitness and overweight/obesity.

# Chapter 4 Aerobic Fitness, Physical Activity and Body Composition in Asthmatic Children and Adolescents

## 4.1 Introduction

Asthma prevalence increased worldwide throughout the second half of last century (Magnus & Jaakkola, 1997) and despite the most recent evidence of a downturn among Australian children, approximately 20% remain affected by the disease (Robertson *et al.*, 2004). Exercise-induced bronchoconstriction reportedly affects a majority of asthmatic children (Milgrom & Taussig, 1999), which may deter many from participating in regular physical activity given the associated fear of breathlessness and unpleasant sensations. This has given rise to the common perception that asthmatic children may have a reduced capacity for exercise. However, little evidence supports this position (Varray *et al.*, 1989; Counil *et al.*, 2001; Wong *et al.*, 2001). What is clear though is that (i) few attempts have been made to examine fitness within the full spectrum of asthma severity in a single study, and (ii) fitness data for severe asthmatics is lacking.

Several health benefits exist for children and adolescents who partake in regular physical activity. Greater cardio-respiratory fitness (Rowlands *et al.*, 1999), improved ventilatory capacity and performance (Åstrand & Rodahl, 1986; Dencker *et al.*, 2006), and lower body fat levels (Craig *et al.*, 1996; Moore *et al.*, 2003) are some of these benefits. Conversely, a lack of physical activity has been associated with lower levels of cardio-respiratory fitness

(National Institutes of Health, 1996) and an increased prevalence of overweight and obesity (Yu *et al.*, 2002). It would therefore be reasonable to suggest that low levels of physical activity among asthmatic children would also lead to reductions in cardio-respiratory fitness and increase the likelihood of reaching a ventilatory limitation at modest levels of exercise intensity. If such a limitation was established, neither chronic medication use nor pre-medication prior to exercise would alleviate the restriction. Moreover, a reduced cardio-respiratory fitness would also result in a higher ventilation for a given work load, thereby creating a greater stimulus for exercise-induced bronchoconstriction (Orenstein, 2002). Such a situation may act as a deterrent to exercise in the asthmatic child and may also manufacture a self-limiting cycle of inactivity. Consequently, an asthmatic child may not be as physically equipped to cope with a bout of exercise-induced bronchoconstriction as well as they may if they possessed a level of aerobic fitness comparable to that of a physically active, non-asthmatic child. In addition, asthmatic children affected in such a way would be likely further disadvantaged in that their asthma may be poorly controlled (Fink *et al.*, 1993) and their prospects of a healthy adult life lowered (National Institutes of Health, 1996; Yu *et al.*, 2002). The concept that asthmatic children may have a ventilatory limitation to exercise suggests that the relationship between physical activity and aerobic fitness is likely to be more pronounced than the postulated smaller association observed in healthy, non-asthmatic children (as reported in Chapter 3). If an initial deficit in aerobic fitness is present, then an increase in physical activity would likely result in improvements in aerobic fitness, thereby creating a direct relationship.

The overall increase in asthma prevalence over recent decades has been paralleled by a dramatic increase in the prevalence of obesity in young people in Australia (Magarey *et al.*, 2001). The concurrent increases in the occurrence of both conditions, coupled with the sharing of common risk factors, has brought about the proposal of an asthma-obesity relationship (Tantisira & Weiss, 2001), although the strength of any relationship in children remains unclear (To *et al.*, 2004). Despite support for the premise that obesity is a risk factor for asthma (Chinn & Rona, 2001; Gilliland *et al.*, 2003; Gold *et al.*, 2003), the causality relating obesity and asthma has not yet been established. However, plausible biological mechanisms exist by which obesity may be considered to either cause or worsen asthma (Shore & Johnson, 2006). These include co-morbidities such as gastro-esophageal reflux, breathing at low lung volumes, chronic systemic inflammation, and endocrine factors including adipokines and reproductive hormones (Shore & Johnson, 2006). Notably though, it seems that obesity may be particularly important for the more severe asthmatic (Luder *et al.*, 1998). Specifically, Luder *et al*. (1998) reported that a higher degree of asthma severity was associated with an elevated BMI. One modifiable risk factor common to both diseases is a lowered physical activity involvement (Rowland, 1991; Lang *et al.*, 2004). Concomitantly, exercise may act to reduce some symptoms of asthma-related maladies, as well as influencing other health indicators, such as cardio-respiratory fitness.

Therefore, the aims of this chapter were to (i) establish the influence of asthma and asthma severity on aerobic fitness, physical activity and body composition, (ii) elucidate whether any association exists between asthma and body composition, (iii) determine whether an asthma-obesity relationship exists, and (iv) determine whether significant differences existed between asthmatic and non-asthmatic children in terms of aerobic fitness, physical activity and body composition.

## 4.2 Methodology

### 4.2.1 Participants

Grade 5 and 8 asthmatic children and adolescents aged 10 to 14 years were recruited from government, independent and Catholic schools from metropolitan Melbourne and tested between 2001 and 2004. Participants were classified as asthmatic if they were reported in the ASQ (Rosier *et al.*, 1994) to be currently taking anti-asthma medication.

### 4.2.2 Procedure

At least 10 minutes before spirometry, and prior to performing the 6MRT, asthmatic children were medicated with a bronchodilator - 800µg of Ventolin™ (Salbutamol) via a Volumatic™ spacer and metered dose inhaler (Allen & Hanburys, Uxbridge, United Kingdom). This procedure was applied to avoid or attenuate exercise-induced bronchoconstriction, providing asthmatic participants with the opportunity to perform to maximal effort during the exercise test (i.e. 6MRT). Spirometry was performed by asthmatic participants to ensure they were eligible to partake in the 6MRT. Specifically, $FEV_1$ % predicted was required to be equal to or greater than 75% of predicted normal.

### 4.2.3 Data Management

Data were grouped according to age and gender. Physical activity, aerobic fitness and body composition data were stratified according to asthma severity as determined by responses to the ASQ (Rosier *et al.*, 1994), in order to determine the specific influence of severity. Physical activity and aerobic fitness data were also stratified according to BMI (Cole *et al.*, 2000) and %BF (Taylor *et al.*, 2002) categories to determine the specific influence of body composition on these two parameters. FFM was estimated using the %BF values generated from skinfold thickness measurements, and energy expenditure during the 6MRT was estimated from 6MRD values (see Section 2.2.8, page 116). Maximal predicted heart rate values were calculated using the equation of Spiro (1977) (see Section 3.2.2, page 120). Activity monitor counts were converted to estimated MET values and the time spent in each physical activity intensity range was also calculated (Trost, 2001) (see Section 2.2.5.3, page 113). Non-asthmatic data generated in Chapter 3 (i.e. measures of physical activity, aerobic fitness and body composition) were used throughout this chapter as a comparison against asthmatic data.

### 4.2.4 Statistics

Statistical analysis was performed using *Stata* Version 8.0 (Stata Corporation, Texas, USA). The one-sample Kolmogorov-Smirnov test was employed to test the normality of the data parameters under investigation. All descriptive data were reported as mean and standard deviation. Unpaired *t* tests were used to test if population means estimated by two independent samples differed significantly. This included, for example, comparing mean values of Chapter 4 asthmatic participants according to gender, and also comparing mean values according to asthma status (i.e Chapter 3 non-asthmatic data versus Chapter 4 asthmatic data). One-way analysis of variance (ANOVA) was employed to test for differences in a single dependent variable among three or more groups formed by the categories of a single independent categorical variable. Following the detection of a significant main effect, Sidak post-hoc analyses were performed to locate where significant differences lay. Regression analyses were performed to estimate the predictive power of an independent variable, such as BMI, on a dependent variable, such as 6MRD. Correlation analyses were also performed to determine the interdependence of two variables. Significance levels were set at $p<0.05$. Odds ratios were employed to estimate the association between asthma and markers of body fat. Specifically, odds ratios were calculated for each grade and gender group to determine whether asthmatic participants were more likely to be overweight or obese than the non-asthmatic participants described in Chapter 3. In addition, Mantel-Haenszel estimates were calculated to determine overall odds ratios for the combined grade and gender data.

## 4.3 Results

### 4.3.1 Participants

One hundred and twenty-five grade 5 and 8 asthmatic children and adolescents aged 10 to 14 years were recruited for school testing. Age, height and body mass were greater in grade 8 groups when compared to grade 5 groups of corresponding gender (Table 4.1). Grade 8 males and females were 10.5% ($t[72]=8.01$; $p<0.0001$) and 11.6% taller ($t[49]=9.87$; $p<0.0001$), respectively, when compared to grade 5 males and females. In addition, grade 8 males and females were 39.7% ($t[72]=5.72$; $p<0.0001$) and 41.6% heavier ($t[49]=6.30$; $p<0.0001$), respectively, when compared to grade 5 males and females.

**Table 4.1 Asthmatic participant characteristics**

| | Grade 5 Male (n = 42) | Grade 5 Female (n = 21) | Grade 8 Male (n = 32) | Grade 8 Female (n = 30) |
|---|---|---|---|---|
| **Age (years)** | 11.04 ± 0.50$^{\dagger}$ | 10.80 ± 0.40$^{\dagger}$ | 13.6 ± 0.45 | 14.03 ± 0.43 |
| **Height (cm)** | 146.9 ± 6.2$^{\dagger}$ | 144.5 ± 7.4$^{\dagger}$ | 162.3 ± 10.2 | 161.2 ± 4.9 |
| **Mass (kg)** | 40.6 ± 9.7$^{\dagger}$ | 40.1 ± 9.0$^{\dagger}$ | 56.7 ± 14.4 | 56.8 ± 9.6 |
| **FM (kg)** | 9.4 ± 5.6$^{\dagger}$ | 11.8 ± 4.4$^{\dagger}$ | 13.3 ± 6.7 | 15.7 ± 8.0 |
| **FFM (kg)** | 31.2 ± 5.2$^{*\dagger}$ | 28.3 ± 4.9$^{\dagger}$ | 43.4 ± 8.9 | 41.1 ± 7.4 |
| **FM:FFM Ratio** | 0.34 ± 0.14 | 0.33 ± 0.13 | 0.30 ± 0.15 | 0.38 ± 0.16 |

Mean ± SD
$^{\dagger}$ significantly different from grade 8 group of the same gender ($p<0.0001$)

* significantly different from females of the same age ($p<0.0001$)

## 4.3.2 Testing Data Distribution for Normality

The Kolmogorov-Smirnov test results for all data variables are shown in Table 4.2 (Appendix M: Chapter 4 Appendices). All data sets were normally distributed.

## 4.3.3 Lung Function

Post-bronchodilator $FEV_1$ % predicted and FVC % predicted were within a normal healthy range (Zapletal *et al.*, 1987) for all participants. No differences in $FEV_1$ % predicted were reported when comparing groups by age or gender, nor were differences observed in FVC % predicted or forced expiratory ratio (FER). Post-bronchodilator results for spirometric indices are shown in Table 4.3.

**Table 4.3 Post-bronchodilator lung function of 10-14 year old asthmatic participants**

| | **Grade 5 Male** (n = 42) | **Grade 5 Female** (n = 21) | **Grade 8 Male** (n = 32) | **Grade 8 Female** (n = 30) |
|---|---|---|---|---|
| **$FEV_1$ (l)** | 2.40 ± 0.41 | 2.10 ± 0.40 | 3.30 ± 0.72 | 2.90 ± 0.50 |
| **$FEV_1$ (% Predicted)** | 103.8 ± 12.8 | 99.5 ± 13.9 | 106.0 ± 12.0 | 98.1 ± 24.3 |
| **FVC (l)** | 2.60 ± 0.50 | 2.25 ± 0.47 | 3.61 ± 0.77 | 3.10 ± 0.62 |
| **FVC (% Predicted)** | 94.3 ± 15.6 | 92.4 ± 12.6 | 96.6 ± 12.2 | 93.6 ± 16.1 |
| **FER ($FEV_1$/FVC)** | 92.6 ± 7.4 | 93.8 ± 7.8 | 90.8 ± 6.7 | 93.3 ± 8.0 |

Mean ± SD

#### 4.3.3.1 Lung function comparative analysis – non-asthmatic versus asthmatic values

No differences were observed in any of the spirometric indices listed in Table 4.3 when comparing non-asthmatic and post-bronchodilator asthmatic values (see Table 4.4, Appendix M: Chapter 4 Appendices). Comparisons of non-asthmatic and asthmatic mean FER values grouped by grade and gender are shown in Figure 4.1.

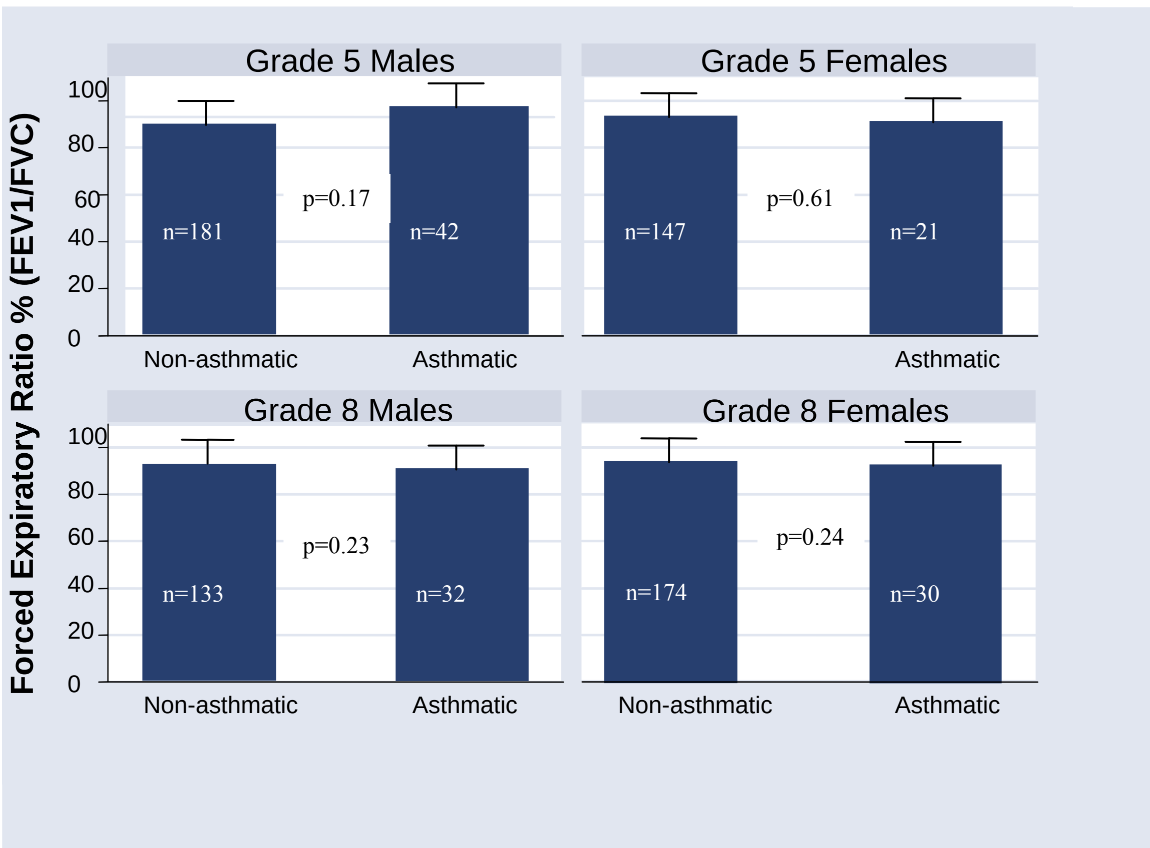



**Figure 4.1 Comparison of non-asthmatic (n=635) and asthmatic (n=125) forced expiratory ratio (FER) data grouped according to grade and gender.** Bar graphs show mean FER values.

### 4.3.4 Asthma Severity - Asthma Symptoms Questionnaire (ASQ)

Mean ASQ values for each grade and gender group are shown in Table 4.5. All groups fell within the mild severity range, with the exception of grade 8 females whose mean was in the moderate severity range. Grade 8 females had a 63.4% greater (t[60]=2.61; p=0.01) ASQ score when compared to age-matched males. No other significant differences were found when comparing groups by grade and gender. Mean ASQ values categorised by severity range are shown in Table 4.6 and illustrated in Figure 4.2. For the purpose of analysis, moderate and severe groups were combined. Forty-five (36%) asthmatic participants were classified with trivial asthma, with 39 (31.2%) were in the mild category, 28 (22.4%) in the moderate category and 13 (10.4%) in the severe category. No differences were found when comparing mean ASQ values of the same severity.

**Table 4.5 Asthma severity (ASQ) results of 10-14 year old asthmatic participants according to the Rosier *et al*. (1994) asthma severity scale**

| | **Grade 5 Male** (n = 42) | **Grade 5 Female** (n = 21) | **Grade 8 Male** (n = 32) | **Grade 8 Female** (n = 30) |
|---|---|---|---|---|
| **ASQ** | 6.80 ± 3.8 | 6.95 ± 3.9 | 5.75 ± 3.4* | 9.40 ± 4.3 |

Mean ± SD

* significantly different from females of the same age  (p<0.02)

**Table 4.6 ASQ scores categorised by Rosier *et al*. (1994) asthma severity scale**

| ASQ Classification | Grade 5 Male (n=42) | Grade 5 Female (n = 21) | Grade 8 Male (n = 32) | Grade 8 Female (n = 30) |
|---|---|---|---|---|
| **Trivial** | 2.30 ± 1.60 (n=14) | 3.30 ± 0.76 (n=7) | 2.13 ± 1.24 (n=15) | 2.44 ± 1.01 (n=9) |
| **Mild** | 6.20 ± 1.22 (n=16) | 6.44 ± 1.33 (n=9) | 6.00 ± 1.20 (n=8) | 6.80 ± 1.30 (n=6) |
| **Moderate/Severe** | 12.90 ± 3.80 (n=12) | 13.00 ± 2.12 (n=5) | 11.60 ± 3.10 (n=9) | 14.40 ± 4.32 (n=15) |

Mean ± SD

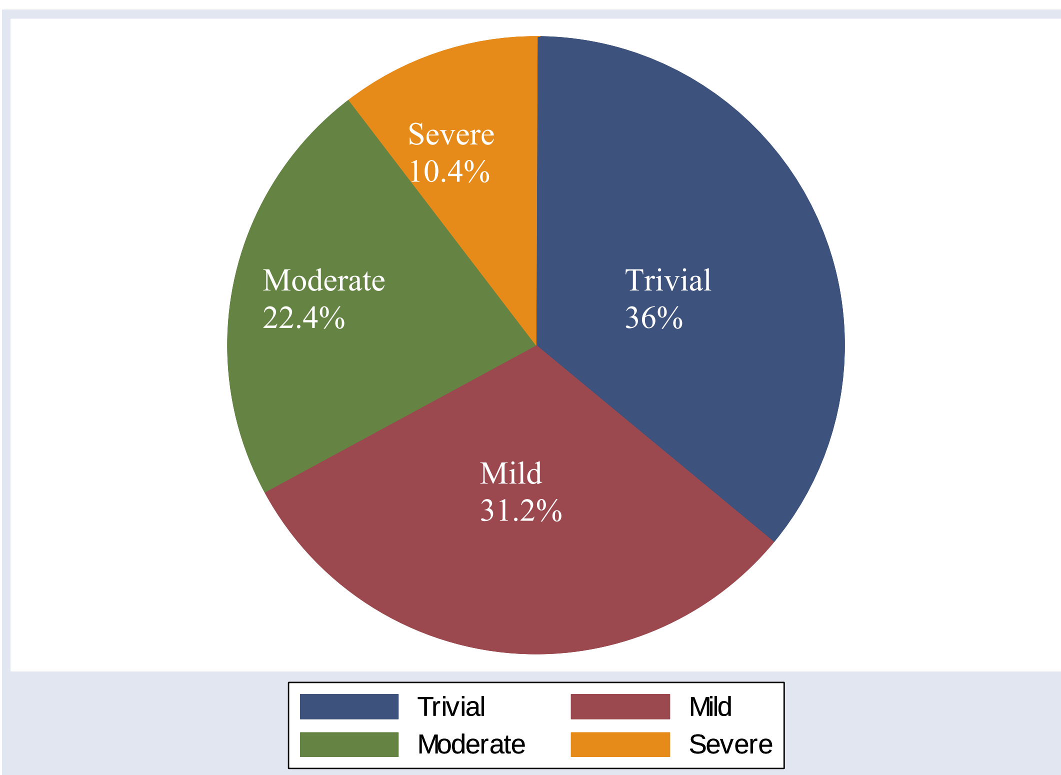



**Figure 4.2 Percentage distribution of asthmatic participants (n=125) according to the asthma severity classifications of Rosier *et al*. (1994).**

### 4.3.5 Body Composition – BMI and %BF

Mean BMI and %BF values for each grade and gender are shown in Table 4.7. Mean BMI values of grade 5 males and females were 12.3% lower (t[72]=2.97; p=0.004) and 12.9% lower (t[49]=3.02; p=0.003), respectively, than their gender-matched peers from grade 8. In addition, compared to females of the same age, %BF values of grade 5 and 8 males were 22.9% lower (t[61]=3.73; p=0.0004) and 28.3%(t[60]=5.90; p<0.0001), respectively..

**Table 4.7 Body composition characteristics of 10-14 year old asthmatic participants**

| | **Grade 5 Male** (n = 42) | **Grade 5 Female** (n = 21) | **Grade 8 Male** (n = 32) | **Grade 8 Female** (n = 30) |
|---|---|---|---|---|
| **BMI** | $18.7 \pm 3.6^{\dagger}$ | $19.0 \pm 3.1^{\dagger}$ | $21.3 \pm 4.0$ | $21.8 \pm 3.2$ |
| **%BF** | $22.2 \pm 7.3$* | $28.8 \pm 4.7$ | $22.3 \pm 6.5$* | $31.1 \pm 4.3$ |

Mean ± SD
* significantly different from females of the same age (p<0.05)

† significantly different from grade 8 group of the same gender (p<0.0001)

#### 4.3.5.1 Body composition comparative analyses – non-asthmatic versus asthmatic values

No differences in mean BMI or mean %BF values were shown when comparing non-asthmatic and asthmatic values grouped according to age and gender (see Table 4.8, Appendix M: Chapter 4 Appendices). However, 30.4% and 40.8% of asthmatic participants were categorised overweight or obese when additional classifications were applied for BMI (Cole *et al.*, 2000) and %BF (Taylor *et al.*, 2002), respectively. The prevalence rates are considerably greater than those observed in the non-asthmatic youth (21.1% using BMI cutoff points (Cole *et al.*, 2000) and 33.3% using %BF cutoff points (Taylor *et al.*, 2002)) in Chapter 3.

### 4.3.6 Aerobic Fitness Data – 6MRD, 6MRD/FFM and Predicted Peak $\dot{V}O_2$

Mean 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and peak heart rate values are shown in Table 4.9. No differences were observed in peak heart rate between grade and gender groups, and all groups achieved a peak heart rate above 90% of their predicted maximum. Grade 5 and 8 males recorded 17.7% greater ($t[61]=4.35$; $p=0.0001$) and 13.8% greater ($t[60]=2.90$; $p=0.005$) 6MRD values, respectively, when compared to females of the same age (Figure 4.3). However, no significant differences were reported in 6MRD between grade levels for males or females.

Similarly, grade 5 and 8 males recorded 10.5% greater ($t[61]=3.51$; $p=0.0009$) and 8.7% greater ($t[60]=2.24$; $p=0.02$) predicted peak $\dot{V}O_2$ values, respectively, when compared to grade 5 and 8 females. No significant differences were observed in predicted peak $\dot{V}O_2$

values between grade levels for males or females. In addition, grade 5 males and females had 31.1% greater (t[72]=4.18; p=0.0001) and 28.2% greater (t[49]=4.12; p=0.0001) mean 6MRD/FFM values, respectively when compared to grade 8 males and females.

**Table 4.9 Aerobic fitness of 10-14 year old asthmatic participants**

| | **Grade 5 Male** (n = 42) | **Grade 5 Female** (n = 21) | **Grade 8 Male** (n = 32) | **Grade 8 Female** (n = 30) |
|---|---|---|---|---|
| **6MRD (m)** | 1101.3 ± 136.0* | 935.7 ± 155.1 | 1157.5 ± 218.7* | 1017.1 ± 149.1 |
| **6MRD/FFM (m/kg)** | 36.7 ± 9.0† | 34.1 ± 8.3† | 28.0 ± 8.5 | 26.6 ± 6.3 |
| **Predicted peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 47.2 ± 4.5* | 42.7 ± 5.2 | 46.0 ± 7.3* | 42.3 ± 5.0 |
| **Heart Rate (bpm)** | 195.6 ± 10.7 | 191.3 ± 14.0 | 193.2 ± 10.6 | 188.2 ± 13.4 |
| **% Predicted Maximum Heart Rate** | 96.4 ± 0.64 | 94.2 ± 0.80 | 96.0 ± 0.60 | 93.6 ± 0.74 |

Mean ± SD

* significantly different from females of the same age (p<0.05)

† significantly different from grade 8 group of the same gender (p<0.0001)

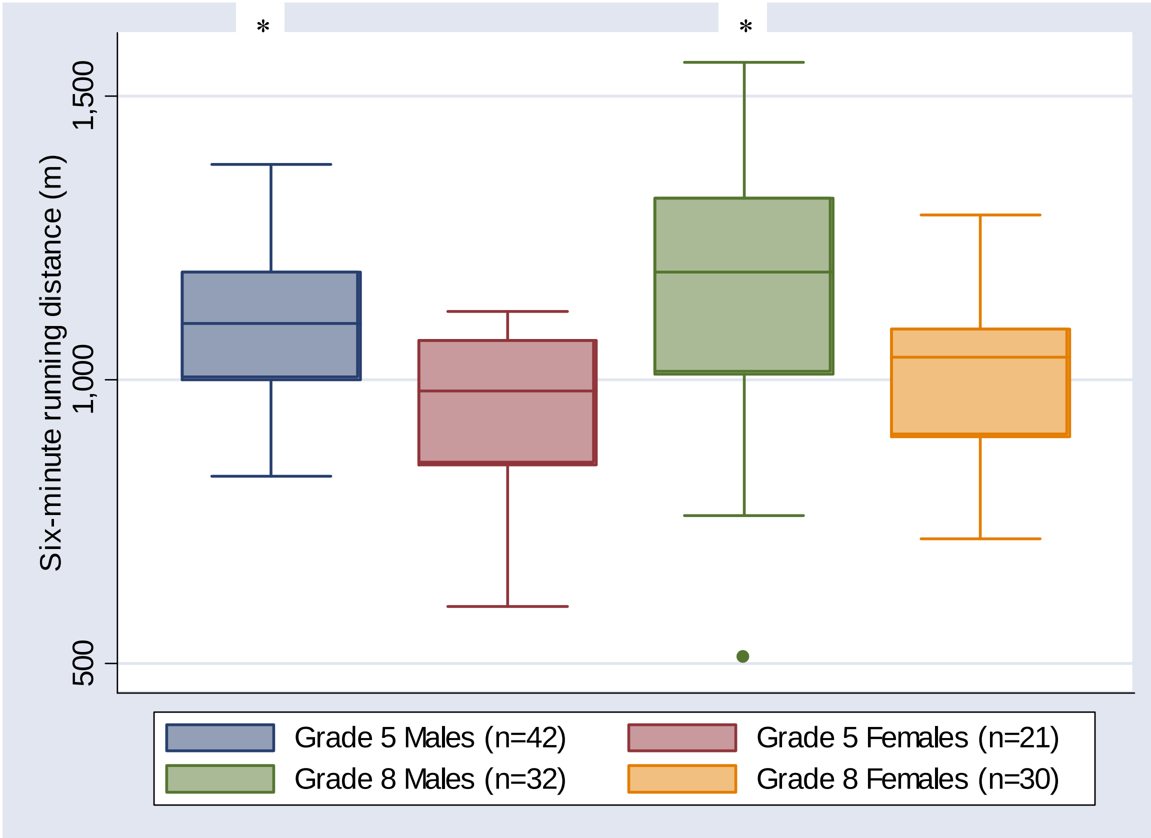



**Figure 4.3 Comparison of six-minute running distances in 125 asthmatic participants aged 10 -14 years, grouped according to grade and gender**. Plots show the mean and 95% confidence intervals. Outliers represent those values outside the 95% confidence interval.

* significantly different from females of the same age (p<0.05)

### 4.3.6.1 Aerobic fitness comparative analyses – non-asthmatic versus asthmatic values

No differences were shown in 6MRD when comparing non-asthmatic and asthmatic participants grouped according to age and gender (see Table 4.10, Appendix M: Chapter 4 Appendices). Comparisons of non-asthmatic and asthmatic mean 6MRD values grouped by grade and gender are illustrated in Figure 4.4.

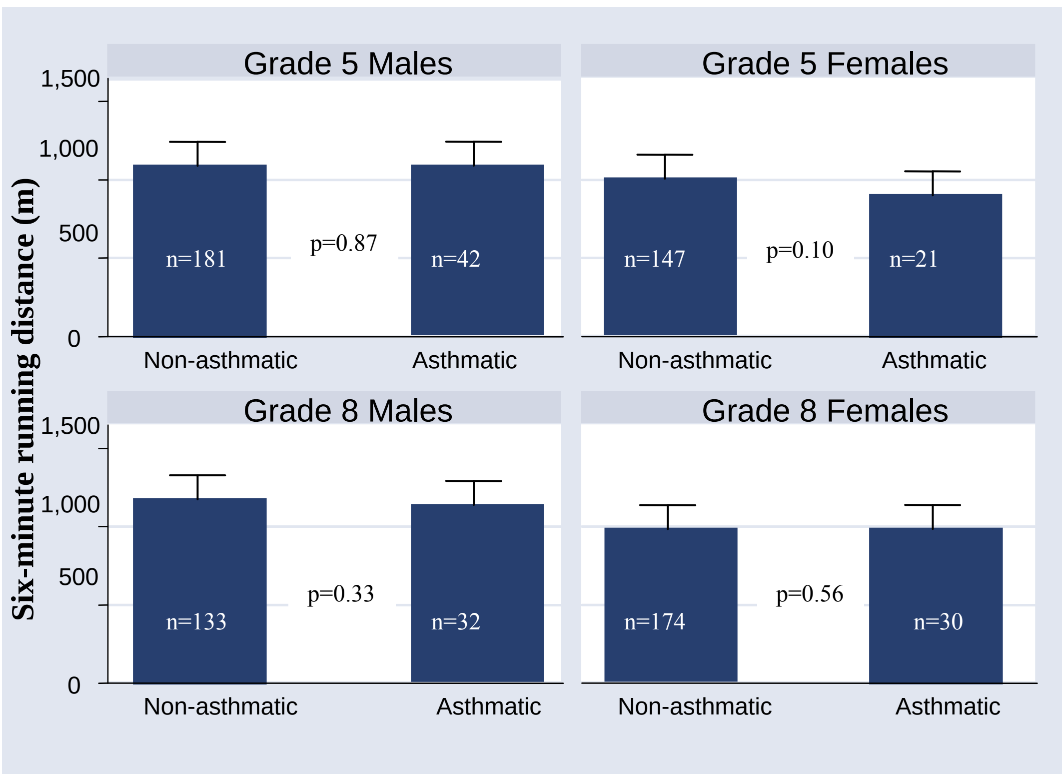



**Figure 4.4 Comparison of non-asthmatic (n=635) and asthmatic (n=125) six-minute running distances grouped according to grade and gender.** Bar graphs show mean six-minute running distances.

### 4.3.7 Physical Activity – PAQ-C, Activity Monitor Counts, Estimated MET

Mean PAQ-C, activity monitor counts and estimated MET values are shown in Table 4.11. Grade 5 and 8 males had 25.1% greater ($t[61]=4.47$; $p<0.0001$) and 25.8% greater ($t[60]=3.86$; $p=0.0003$) mean PAQ-C scores, respectively, when compared to females of the same age. Also, grade 5 males had the greatest mean PAQ-C overall, which was 10.6% greater ($t[72]=2.14$; $p=0.03$) than the grade 8 males value.

No differences were found between activity monitor counts on account of grade level or gender. However, when activity monitor counts were expressed as estimated MET values, grade 5 males and females had 16.1% greater ($t[10]=2.75$; $p=0.02$) and 12.1% greater ($t[15]=2.24$; $p=0.03$) mean values, respectively, compared to grade 8 males and females, as illustrated in Figure 4.5.

In accordance with age-specific thresholds (Trost, 2001) (see Table 1.1), results for time proportions of daily physical activity according to intensity ranges are shown in Table 4.12 (Appendix M: Chapter 4 Appendices). No between-group differences for age or gender were reported for the time spent in the different physical activity intensity levels.

**Table 4.11 Physical activity of 10-14 year old asthmatic participants**

| | Grade 5 Male | Grade 5 Female | Grade 8 Male | Grade 8 Female |
|---|---|---|---|---|
| **PAQ-C** | 3.34 ± 0.61*† (n = 42) | 2.67 ± 0.42 (n = 21) | 3.02 ± 0.64* (n = 32) | 2.40 ± 0.65 (n = 30) |
| **Activity Monitor Counts (counts/min)** | 431.9 ± 188.0 (n=6) | 320.5 ± 168.5 (n=9) | 390.9 ± 181.4 (n=6) | 385.6 ± 161.3 (n=8) |
| **Estimated MET ($ml.kg^{-1}.min^{-1}$)** | 2.24 ± 0.21† (n=6) | 2.13 ± 0.19† (n=9) | 1.93 ± 0.18 (n=6) | 1.90 ± 0.26 (n=8) |

Mean ± SD

* significantly different from females of the same age (p<0.05)

† significantly different from grade 8 group of the same gender (p<0.05)

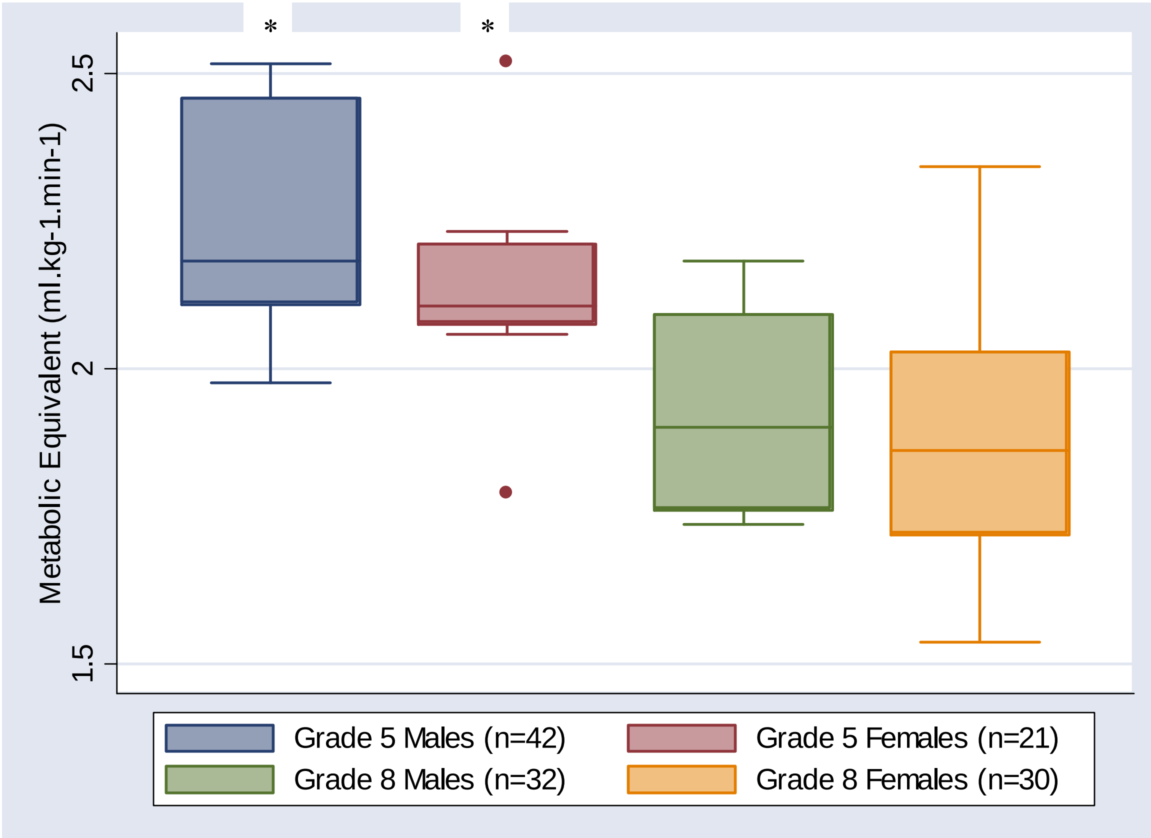



**Figure 4.5 Comparison of estimated metabolic equivalent values in 125 asthmatic participants aged 10 -14 years, grouped according to grade and gender**. Plots show the mean and 95% confidence intervals. Outliers represent those values outside the 95% confidence interval.

* significantly different from grade 8 group of the same gender ($p<0.05$)

### 4.3.7.1 Physical activity comparative analyses – non-asthmatic versus asthmatic values

No differences in mean PAQ-C, activity monitor counts or MET values were shown when comparing non-asthmatic and asthmatic values grouped according to grade and gender, except for the comparison of grade 5 female non-asthmatic and asthmatic PAQ-C results (see Table 4.13, Appendix M: Chapter 4 Appendices).

### 4.3.8 Asthma Severity - ASQ

### 4.3.8.1 Body composition and ASQ

Mean BMI and %BF values grouped by ASQ are shown in Table 4.14 (Appendix M: Chapter 4 Appendices). Regression analysis results for the relationships between BMI, %BF and ASQ are displayed in Table 4.15 (Appendix M: Chapter 4 Appendices) and illustrated in Figure 4.6 (combined asthmatic participant data). For each grade and gender, no differences in mean BMI or mean %BF were shown when comparing groups according to asthma severity. Furthermore, none of the regression analysis results reached significance. Therefore, body composition was not influenced by asthma severity.


**Figure 4.6 Scatterplots of body fat markers versus asthma severity in 125 asthmatic males and females aged 10 to 14 years.** Scatterplots show a lack of association between ASQ and BMI and between ASQ and %BF. BMI = Body mass index.

Regression analysis equations for the combined data set (n=125):

ASQ = 0.12 (BMI) + 4.80 ($R^2$=0.01; p=0.34)

ASQ = 0.13 (%BF) + 3.60 ($R^2$=0.04; p=0.15)

### 4.3.8.2 Aerobic fitness and ASQ

Mean 6MRD, 6MRD/FFM and predicted peak $\dot{V}O_2$ values as categorised by ASQ are shown in Table 4.16 (Appendix M: Chapter 4 Appendices). Regression analysis results for the relationships between aerobic fitness and ASQ are shown in Table 4.17 (Appendix M: Chapter 4 Appendices) and illustrated in Figure 4.7 (combined asthmatic participant data). For each grade and gender, no differences in mean 6MRD, 6MRD/FFM or predicted peak $\dot{V}O_2$ were observed when comparing groups according to asthma severity. Regression analysis revealed only one significant finding, which was a positive relationship between 6MRD/FFM and ASQ in grade 5 males [6MRD/FFM = 0.63 (ASQ) + 32.6; $R^2 = 0.10$, $p=0.03$]. This particular finding suggests that a greater level of asthma severity among grade 5 males at least partially accounts for a greater running performance, corrected for fat free mass. However, when considering all grade and gender groups these findings taken together indicate that asthma severity did not influence aerobic fitness.

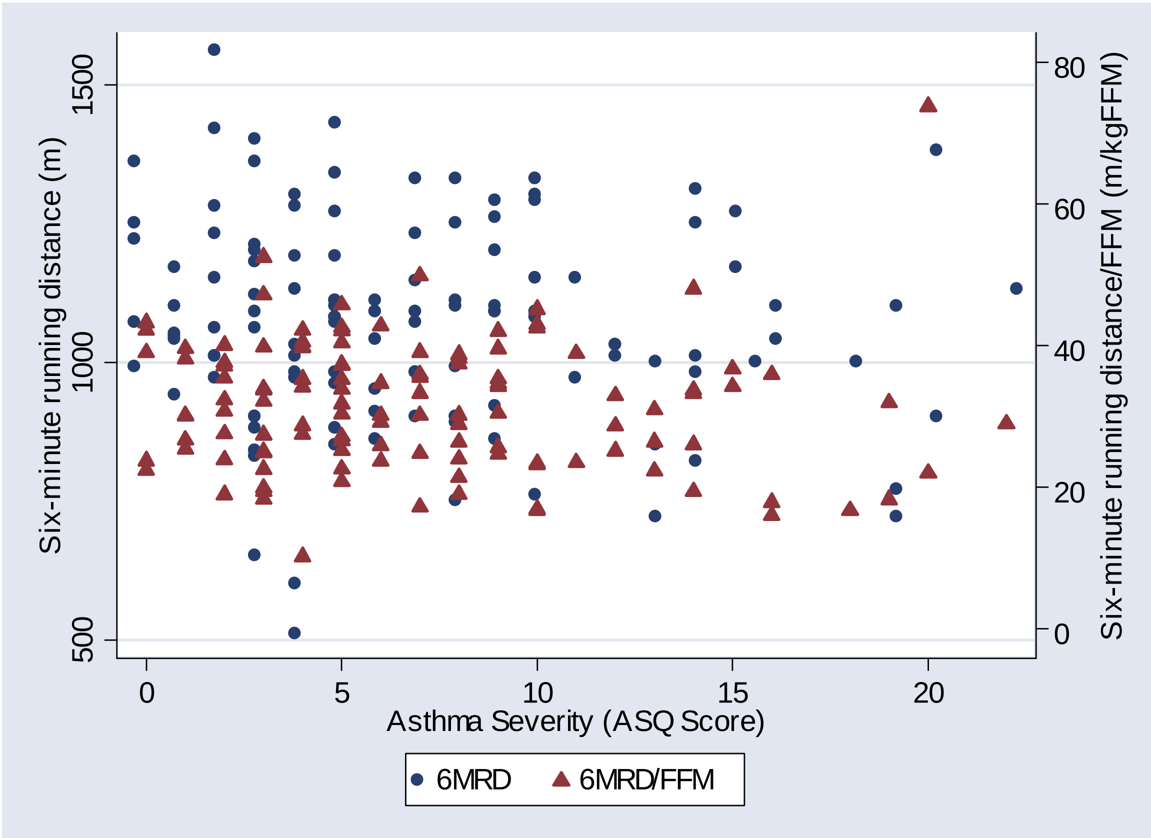



**Figure 4.7 Scatterplots of estimates of aerobic fitness versus asthma severity in 125 asthmatic males and females aged 10 to 14 years.** Scatterplots demonstrate a lack of relationship between ASQ and 6MRD and between ASQ and 6MRD/FFM. 6MRD = six-minute running distance; 6MRD/FFM = six-minute running distance per kilogram of fat free mass.

Regression analysis equations for the combined data set (n=125):

ASQ = -0.003 (6MRD) + 10.01 ($R^2$=0.01; p=0.28)

ASQ = -0.03 (6MRD/FFM) + 8.00 ($R^2$=0.003; p=0.52)

### 4.3.8.3 Physical activity and ASQ

Mean PAQ-C values as categorised by ASQ are shown in Tables 4.18 (Appendix M: Chapter 4 Appendices), while correlation analysis results for activity monitor counts and MET versus ASQ are shown in Table 4.19 (Appendix M: Chapter 4 Appendices). Due to the small sample size, activity monitor counts and MET values were not subdivided into ASQ categories of Rosier *et al.* (1994). Regression analysis results for the relationships between measures of physical activity and ASQ are shown in Table 4.20 (Appendix M: Chapter 4 Appendices) and illustrated in Figure 4.8 (combined asthmatic participant data). For each grade and gender, no differences in mean PAQ-C were shown when groups were compared according to asthma severity. Furthermore, both correlation and regression analysis revealed no significant findings. As such, physical activity was not influenced by asthma severity.


**Figure 4.8 Scatterplots of physical activity measurements versus asthma severity in 125 asthmatic males and females aged 10 to 14 years.** Scatterplots demonstrate a lack of relationship between ASQ and each measure of physical activity. PAQ-C = Physical Activity Questionnaire for Children; MET = metabolic equivalent; AMC = activity monitor counts.

Regression analysis equations:

ASQ = -0.67 (PAQ-C) + 9.03 ($R^2$=0.01; p=0.31)

ASQ = -0.002 (Activity Monitor Counts) + 7.64 ($R^2$=0.01; p=0.68)

ASQ = -1.10 (Estimated MET) +9.10 ($R^2$=0.002; p=0.79)

### 4.3.9 Relationship between Activity Monitor Counts and PAQ-C

Results for the relationship between activity monitor counts and PAQ-C are shown in Table 4.21 (Appendix M: Chapter 4 Appendices). Grade 5 males demonstrated an inverse association ($r = -0.38$; $p=0.14$), while all other groups demonstrated positive associations. However, only the grade 8 female group reached significance, with an $R^2 = 0.61$ ($p=0.02$) denoting that 61% of the variance in activity monitor counts could be explained by PAQ-C scores.

### 4.3.10 Relationship between Aerobic Fitness and Body Composition

#### 4.3.10.1 Aerobic fitness when stratified according to BMI and %BF

Mean 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and peak heart rate values categorised by gender- and age-specific BMI cutoff points (Cole *et al.*, 2000) are shown in Table 4.22. The low number of participants classified as obese precluded separate analysis. Regression analysis findings are displayed in Table 4.23 (Appendix M: Chapter 4 Appendices) and illustrated in Figure 4.9 (combined data).

Grade 5 males in the normal BMI group had a 35.4% greater ($t[40]=3.73$; $p=0.0006$) 6MRD/FFM value when compared to the corresponding overweight/obese group. Furthermore, regression analysis revealed significant inverse associations between BMI and each of 6MRD ($R^2=0.20$), 6MRD/FFM ($R^2=0.59$) and predicted peak $\dot{V}O_2$ ($R^2=0.20$) among grade 5 males.

For grade 5 females, the normal BMI group had a 21.1% greater (t[19]=2.37; p=0.02) 6MRD value, a 50.4% greater (t[19]=3.75; p=0.001) 6MRD/FFM value and a 14.8% greater (t[19]=2.37; p=0.02) predicted peak $\dot{V}O_2$ value when compared to the corresponding overweight/obese group. Regression analysis showed a significant inverse association between BMI and 6MRD/FFM ($R^2$=0.66) in grade 5 females.

Among grade 8 males, the normal BMI group had a 24.6% greater (t[30]=3.65; p=0.001) 6MRD value, a 58.5 % greater (t[30]=5.23; p<0.0001) 6MRD/FFM value and a 20.1% greater (t[30]=3.65; p=0.001) predicted peak $\dot{V}O_2$ value when compared to the overweight/obese group of corresponding age and gender. In addition, grade 8 males demonstrated significant inverse associations between BMI and each of 6MRD ($R^2$=0.37), 6MRD/FFM ($R^2$=0.65) and predicted peak $\dot{V}O_2$ ($R^2$=0.37).

For grade 8 females, the normal BMI group had an 37.2% greater (t[28]=3.16; p=0.003) 6MRD/FFM value when compared to the corresponding overweight/obese group. Moreover, regression analysis for grade 8 females revealed significant inverse associations between each measure of aerobic fitness and BMI; 6MRD ($R^2$=0.20), 6MRD/FFM ($R^2$=0.58) and predicted peak $\dot{V}O_2$ ($R^2$=0.20).

**Table 4.22 Aerobic fitness and heart rate responses stratified according to the BMI categories of Cole *et al*. (2000)**

| Group | Variable | Normal BMI | Overweight/Obese BMI |
|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | 1127.0 ± 147.4 | 1037.5 ± 73.5 |
| | **6MRD/FFM** (m/kgFFM) | 39.4 ± 8.4* | 29.1 ± 5.2 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 48.0 ± 4.9 | 45.0 ± 2.4 |
| | **Heart Rate** (bpm) | 196.5 ± 10.0 | 193.3 ± 12.2 |
| | | (n = 30) | (n = 12) |
| **Grade 5 Females** | **6MRD** (m) | 976.3 ± 138.5* | 806 ± 144.3 |
| | **6MRD/FFM** (m/kgFFM) | 37.0 ± 7.0* | 24.6 ± 3.8 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 44.1 ± 4.6* | 38.4 ± 4.8 |
| | **Heart Rate** (bpm) | 191.4 ± 14.3 | 191.0 ± 14.5 |
| | | (n = 16) | (n = 5) |
| **Grade 8 Males** | **6MRD** (m) | 1250.0 ± 173.9* | 1003.3 ± 202.7 |
| | **6MRD/FFM** (m/kgFFM) | 32.5 ± 16.9* | 20.5 ± 10.2 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 49.0 ± 5.6* | 40.8 ± 6.7 |
| | **Heart Rate** (bpm) | 196.2 ± 8.8 | 188.4 ± 11.7 |
| | | (n = 20) | (n = 12) |
| **Grade 8 Females** | **6MRD** (m) | 1049.2 ± 157.2 | 946.0 ± 103.5 |
| | **6MRD/FFM** (m/kgFFM) | 29.1 ± 6.3* | 21.2 ± 3.2 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 43.3 ± 5.2 | 40.0 ± 3.4 |
| | **Heart Rate** (bpm) | 188.5 ± 15.3 | 187.5 ± 8.6 |
| | | (n = 21) | (n = 9) |

Mean ± SD

*significantly different from overweight/obese group of the same variable, age and gender ($p<0.05$)

Mean 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and peak heart rate values stratified according to age and gender-specific %BF cutoff points (Taylor *et al.*, 2002) are shown in Table 4.24, while regression analysis results are displayed in Table 4.25 (Appendix M: Chapter 4 Appendices) and illustrated in Figure 4.9 (combined data).

Grade 5 males who were in the normal %BF group had an 8.7% greater ($t[40]=2.28$; $p=0.02$) 6MRD value and a 21.4% greater ($t[40]=2.68$; $p=0.01$) 6MRD/FFM value when compared to the overweight/obese %BF group of the same grade. Regression analysis revealed significant inverse associations between %BF and each of 6MRD ($R^2=0.15$), 6MRD/FFM ($R^2=0.25$) and predicted peak $\dot{V}O_2$ ($R^2=0.15$).

Grade 5 females classified in the normal %BF range had a 33.2% greater ($t[19]=2.93$; $p=0.008$) 6MRD/FFM value when compared to grade 5 females within the overweight/obese %BF range. A significant inverse association was also found between %BF and 6MRD/FFM ($R^2=0.36$) in grade 5 females.

Grade 8 males in the normal %BF group had a 19.2% greater ($t[30]=2.79$; $p=0.009$) 6MRD value, a 37.5% greater ($t[30]=3.22$; $p=0.003$) 6MRD/FFM value and a 15.7% greater ($t[30]=2.79$; $p=0.009$) predicted peak $\dot{V}O_2$ value when compared to grade 8 males in the overweight/obese %BF group. Furthermore, regression analysis revealed significant inverse associations between %BF and each of 6MRD ($R^2=0.39$), 6MRD/FFM ($R^2=0.38$) and predicted peak $\dot{V}O_2$ ($R^2=0.39$) among grade 8 males.

Grade 8 females in the normal %BF group had 15.4 % greater ($t[28]=2.80$; $p=0.009$) 6MRD, 39.4% greater ($t[28]=5.10$; $p<0.0001$) 6MRD/FFM and 13.7% greater ($t[28]=2.80$; $p=0.009$) predicted peak $\dot{V}O_2$ values when compared to the grade 8 female overweight/obese %BF group. Furthermore, regression analysis revealed significant inverse associations for each of 6MRD ($R^2=0.40$), 6MRD/FFM ($R^2=0.61$) and predicted peak $\dot{V}O_2$ ($R^2=0.40$) when compared against %BF for grade 8 females.

Therefore, taken together, this data indicates that aerobic fitness is significantly inversely related to markers of body fat among this population.

**Table 4.24 Aerobic fitness and heart rate responses as categorised by %BF strata of Taylor *et al*. (2002)**

| Group | Variable | Normal %BF | Overweight/Obese %BF |
|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | 1144.8 ± 153.6* | 1053.5 ± 96.1 |
| | **6MRD/FFM** (m/kgFFM) | 40.3 ± 10.0* | 33.2 ± 4.8 |
| | **Predicted Peak** $\dot{V}$ **$O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 48.6 ± 5.1 | 45.8 ± 3.2 |
| | **Heart Rate** (bpm) | 195.5 ± 11.9 | 195.6 ± 9.4 |
| | | (n = 22) | (n = 20) |
| **Grade 5 Females** | **6MRD** (m) | 979.3 ± 146.9 | 848.6 ± 142.1 |
| | **6MRD/FFM** (m/kgFFM) | 37.3 ± 7.4* | 28.0 ± 6.3 |
| | **Predicted Peak** $\dot{V}$ **$O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 44.2 ± 4.9 | 39.8 ± 4.7 |
| | **Heart Rate** (bpm) | 191.9 ± 15.3 | 190.0 ± 12.0 |
| | | (n = 14) | (n = 7) |
| **Grade 8 Males** | **6MRD** (m) | 1238.4 ± 186.3* | 1039.2 ± 214.5 |
| | **6MRD/FFM** (m/kgFFM) | 31.5 ± 7.5* | 22.9 ± 7.5 |
| | **Predicted Peak** $\dot{V}$ **$O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 48.6 ± 6.2* | 42.0 ± 7.1 |
| | **Heart Rate** (bpm) | 194.0 ± 12.2 | 192.1 ± 8.0 |
| | | (n = 19) | (n = 13) |
| **Grade 8 Females** | **6MRD** (m) | 1071.4 ± 136.6* | 928.2 ± 128.4 |
| | **6MRD/FFM** (m/kgFFM) | 29.0 ± 5.3* | 20.8 ± 3.0 |
| | **Predicted Peak** $\dot{V}$ **$O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 44.1 ± 4.5* | 38.8 ± 3.9 |
| | **Heart Rate** (bpm) | 190.0 ± 14.7 | 185.4 ± 11.2 |
| | | (n = 19) | (n = 11) |

Mean ± SD

*significantly different from overweight/obese group of the same variable, age and gender ($p<0.03$)

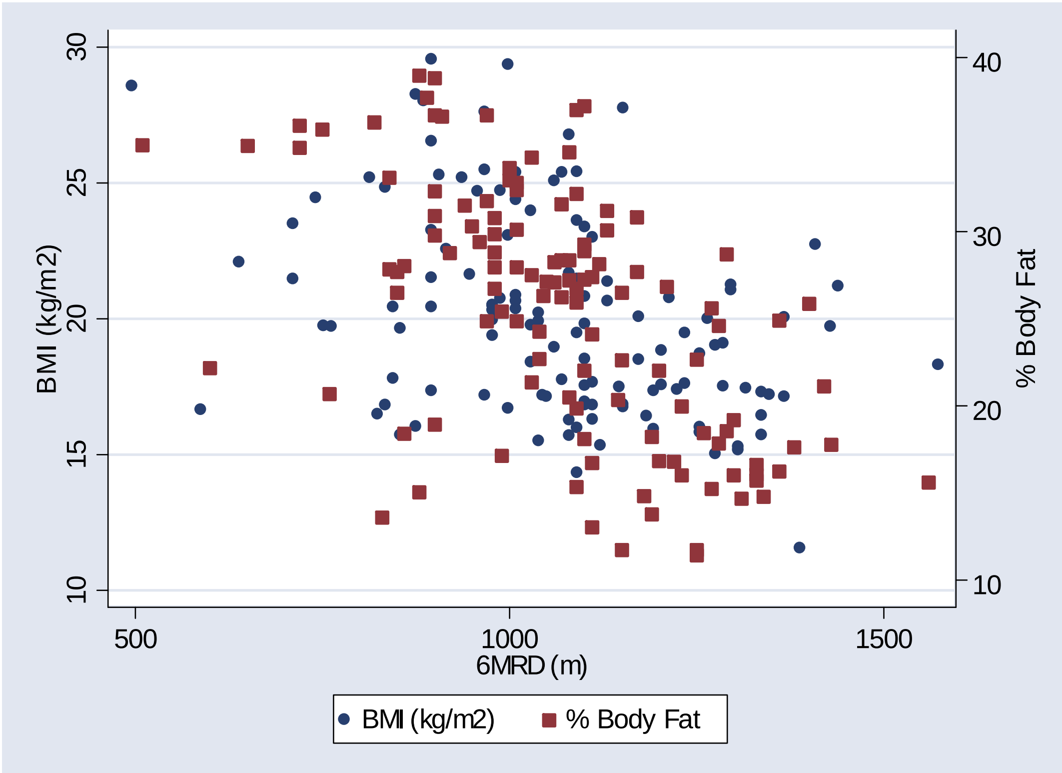



**Figure 4.9 Scatterplots of body fat markers versus six-minute running distance in 125 asthmatic males and females aged 10 to 14 years.** Scatterplots demonstrate significant inverse associations between 6MRD and BMI and between 6MRD and %BF. 6MRD = six-minute running distance, BMI = body mass index.

Regression analysis equations for the combined data set (n=125):

6MRD = -19.4 (BMI) + 1457.8 ($R^2$=0.15; p<0.0001)

6MRD = -14.3 (%BF) + 1432.1 ($R^2$=0.31; p<0.0001)

### 4.3.10.2 Energy expenditure (kJ) and BMI

For grade 5 males, energy expenditure calculated from 6MRD values (see Section 2.2.8, page 116) was 16.8% greater ($t[40]=3.17$; $p=0.002$) among overweight/obese participants when compared to their normal weight-for-age counterparts. No other grade or gender groups demonstrated significant differences. Retrospective sample size calculations revealed that the minimum numbers required to detect significant differences with 80% power in grade 5 females, grade 8 males and grade 8 females were 1380, 2175 and 630, respectively. Energy expenditure values are shown in Table 4.26 (Appendix M: Chapter 4 Appendices).

### 4.3.11 Relationship between Aerobic Fitness and Physical Activity

#### 4.3.11.1 Aerobic fitness, PAQ-C, activity monitor counts and estimated MET

Correlation analysis results for the relationship between 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and PAQ-C are shown in Table 4.27 (Appendix M: Chapter 4 Appendices). Although there were positive associations for each grade and gender group, the only associations to achieve significance were those between 6MRD and PAQ-C, and predicted peak $\dot{V}O_2$ and PAQ-C in male groups.

Correlation analysis results for the relationship between 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and activity monitor counts are shown in Table 4.28 (Appendix M: Chapter 4 Appendices). No results reached significance.

Correlation analysis results for the relationship between 6MRD, 6MRD/FFM, predicted peak $\dot{V}O_2$ and estimated MET are shown in Table 4.29 (Appendix M: Chapter 4 Appendices). Again, no results reached significance. The relationship between each measure of physical activity and 6MRD is illustrated in Figure 4.10 (combined data).

Despite weak significant associations between aerobic fitness and PAQ-C values in males, overall, the current findings indicate that physical activity is not strongly linked to levels of aerobic fitness among this population.

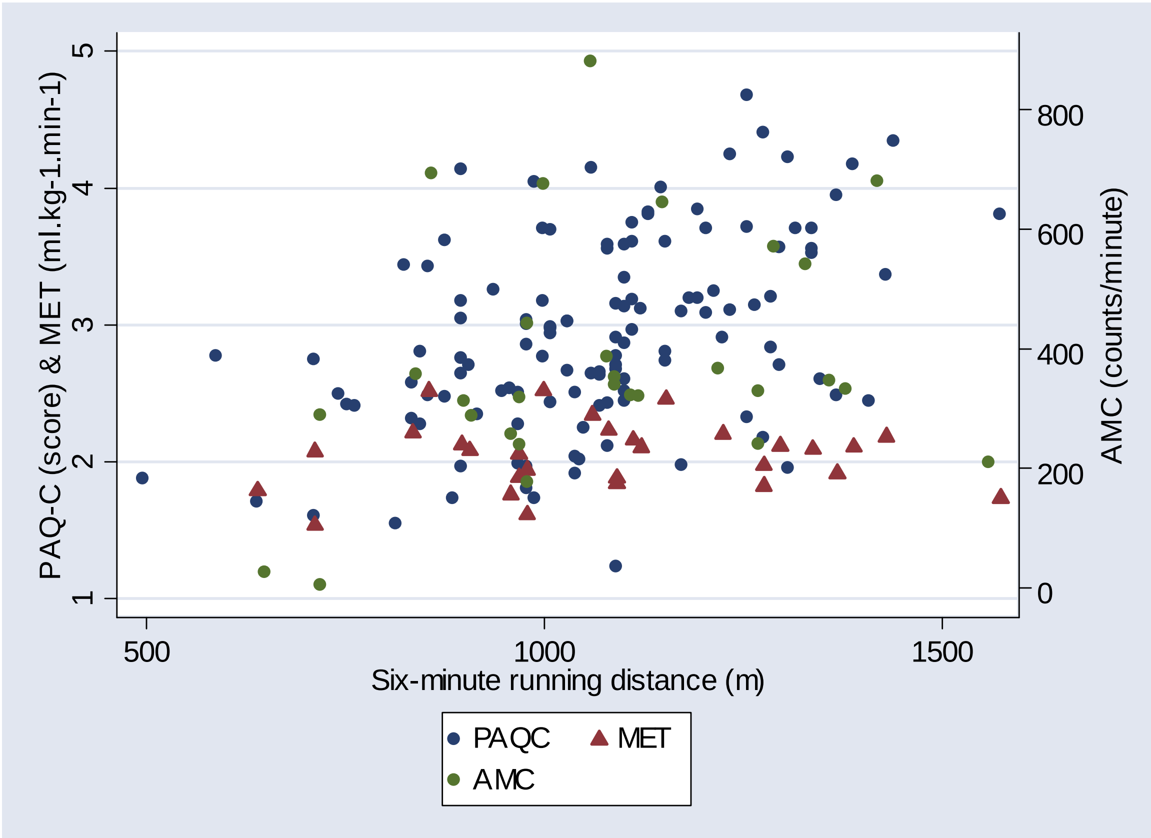



**Figure 4.10 Scatterplots of physical activity measurements versus six-minute running distance in 125 asthmatic males and females aged 10 to 14 years.** Scatterplots demonstrate a significant positive relationship between 6MRD and PAQ-C and a lack of relationship between 6MRD and AMC and between 6MRD and MET. PAQ-C = Physical Activity Questionnaire for Children; MET = metabolic equivalent; AMC = activity monitor counts.

Regression analysis equations:

6MRD = 117.2 (PAQ-C) + 725.8 ($R^2$=0.20; $p<0.0001$)

6MRD = 0.32 (Activity Monitor Counts) + 956.2 ($R^2$=0.08; p=0.13)

6MRD = 48.4 (Estimated MET) + 979.0 ($R^2$=0.002; p=0.78)

### 4.3.12 Relationship between Physical Activity and Body Composition

Mean PAQ-C values categorised by gender and age-specific BMI cutoff points (Cole *et al.*, 2000) are shown in Table 4.30 and regression analysis findings are displayed in Table 4.31 (Appendix M: Chapter 4 Appendices). No differences were found in mean PAQ-C according to BMI classification, although regression analysis demonstrated one significant inverse association between PAQ-C and BMI in grade 8 males. No grade 5 or 8 females were classified as having an obese BMI.

Mean PAQ-C values stratified according to age and gender-specific %BF cutoff points (Taylor *et al.*, 2002) are shown in Table 4.32 and regression analysis results are displayed in Table 4.33 (Appendix M: Chapter 4 Appendices). No differences were found in mean PAQ-C according to %BF classification, and regression analysis demonstrated only one significant association between PAQ-C and %BF which was an inverse relationship in grade 8 males. There were no grade 5 females in the obese %BF group.

Regression analysis results for the relationships between activity monitor counts and the two body composition measures, BMI and %BF are shown in Table 4.34 (Appendix M: Chapter 4 Appendices). No relationships were found between activity monitor counts and BMI or between activity monitor counts and %BF. Due to the small sample size, grades were not subdivided into BMI or %BF categories as outlined by Cole *et al.* (2000) and Taylor *et al.* (2002).

Regression analysis results for the relationships between estimated MET and the two body composition measures, BMI and %BF are shown in Table 4.35 (Appendix M: Chapter 4 Appendices). No relationships were observed between MET and BMI or between METs and %BF.

Collectively, these findings reveal a lack of any significant relationship between markers of body fat and measures of habitual physical activity.

### 4.3.13 Relationship among Physical Activity, Aerobic Fitness, Body Composition and ASQ

Pearson correlation coefficients for the linear associations between BMI, %BF, 6MRD, 6MRD/FFM, PAQ-C, activity monitor counts and ASQ for the combined asthmatic participant sample (i.e. male/female, grade 5/8) are shown in Table 4.36. Predicted peak $\dot{V}O_2$ is not shown as it is derived directly from 6MRD.

**Table 4.36 Pearson correlation coefficients for combined asthmatic participant sample (n=125)**

| Group | BMI | %BF | 6MRD | 6MRD/FFM | PAQ-C | Activity Monitor Counts | ASQ |
|---|---|---|---|---|---|---|---|
| **BMI** | 1.00 | | | | | | |
| **%BF** | 0.73* | 1.00 | | | | | |
| **6MRD** | -0.40* | -0.56* | 1.00 | | | | |
| **6MRD/ FFM** | -0.78* | -0.54* | 0.55* | 1.00 | | | |
| **PAQ-C** | -0.29* | -0.41* | 0.45* | 0.36* | 1.00 | | |
| **Activity Monitor Counts** | -0.07 | -0.19 | 0.29 | 0.10 | 0.46* | 1.00 | |
| **ASQ** | 0.08 | 0.19 | -0.10 | -0.05 | -0.09 | -0.08 | 1.00 |

* significant at p<0.0001 level

### 4.3.14 Odds Ratios and the Relationship between Asthma Status and Body Composition

Odds ratios for asthmatic participants being overweight or obese in comparison to non-asthmatic participants, grouped according to grade and gender, are shown in Table 4.37. Table 4.37 shows that grade 5 asthmatic females are 2.33 times (0.75-7.27) more likely to be overweight in comparison to their non-asthmatic counterparts, when body composition category is assessed according to the BMI cutoff points of Cole *et al.* (2000). Furthermore, grade 5 asthmatic females are 1.21 times (0.45-3.21) more likely to be overweight in comparison to their non-asthmatic counterparts, when body composition category is assessed by the %BF cutoff points of Taylor *et al.* (2002).

Mantel-Haenszel odds ratios for the combined sample of asthmatic participants (n=125) being overweight or obese in comparison to the combined sample of non-asthmatic participants (n=635) are shown in Table 4.38. Table 4.38 shows asthmatic participants are 1.96 times (0.78-4.90) more likely to be obese than non-asthmatic participants when body composition category is assessed according to the BMI cutoff points of Cole *et al.* (2000). In addition, asthmatic participants are 5.40 times (2.00-14.60) more likely to be obese than non-asthmatic participants when the %BF cutoff points of Taylor *et al.* (2002) are used to categorise body composition.

Together, the results highlight a large discrepancy between asthmatic and non-asthmatic participants with respect to body composition. Regardless of the marker used to categorise body fat (i.e. BMI, %BF), asthmatics were more likely to be overweight or obese when compared to non-asthmatic participants.

**Table 4.37 Odds ratios for asthmatic participants (grouped by grade and gender) being overweight or obese in comparison to non-asthmatic participants**

| Group | Odds Ratio For Overweight BMI | Odds Ratio For Overweight %BF | Odds Ratio For Obesity BMI | Odds Ratio For Obesity %BF |
|---|---|---|---|---|
| **Grade 5 Males** | 1.17 (0.51-2.70) | 1.0 (0.48-1.94) | 3.53 (0.74-16.90) | 13.64 (1.24-18.90) |
| **Grade 5 Females** | 2.33 (0.75-7.27) | 1.21 (0.45-3.21) | - | - |
| **Grade 8 Males** | 2.11 (0.84-5.30) | 1.22 (0.54-2.75) | 2.21 (0.52-9.40) | 0.73 (0.10-6.50) |
| **Grade 8 Females** | 1.55 (0.65-3.70) | 1.60 (0.64-4.00) | 1.09 (0.12-9.61) | - |

Odds Ratio (95% CI)

**Table 4.38 Mantel-Haenszel odds ratios for the combined sample of asthmatic participants (n=125) being overweight or obese in comparison to the combined sample of non-asthmatic participants (n=635)**

| Group | Odds Ratio For Overweight | Odds Ratio For Obesity |
|---|---|---|
| BMI | 1.62 (1.03-2.57) | 1.96 (0.78-4.9) |
| %BF | 1.20 (0.78-1.79) | 5.40 (2.00-14.6) |

Odds Ratio (95% CI)

## 4.4 Discussion

Despite the recent suggestion that asthma prevalence has either reached its peak or undergone a downturn, approximately 20% of children in Australia remain affected by the disease (Robertson *et al.*, 2004). Moreover, the prevalence of exercise-induced bronchoconstriction among asthmatic children and adolescents is believed to be between 70 and 90% (Johansson et al., 1997; Wilkerson, 1998). This has given rise to the common perception that asthmatics have a reduced capacity for exercise, despite a recent review questioning this standpoint (Welsh *et al*., 2004). Aerobic conditioning is associated with a reduced risk of exercise-induced bronchoconstriction for a given load, and hence reduced ventilatory task (Carrol & Sly, 1999). When aerobic conditioning goals are combined with the notion that an unrestricted physical activity level is a recognised aim for optimal asthma control (Boulet *et al*., 1999), there is a need to elucidate whether asthmatic children and adolescents display dose responsive deficits in fitness and activity levels.

With an asthma prevalence of 16.4% reported in this study, our sample is representative of the current child/adolescent population in Australia (Robertson *et al.*, 2004). Within the limitation of a convenient sample in the present study, this result adds weight to the view that asthma prevalence has undergone attenuation when compared to a previously reported prevalence rate of 20.0% (Robertson *et al.*, 2004). Possible explanations for the attenuated prevalence include increased attendance at childcare facilities (Oddy *et al.*, 2002) and a previous over-reporting of wheeze (Jenkins *et al.*, 1996).

Of growing interest is that the worldwide rise in asthma prevalence among children and adolescents over the past few decades (Magnus & Jaakkola, 1997) has been paralleled by an escalating incidence of obesity (Magarey *et al.*, 2001). The temporal association in the growing incidence of both conditions, coupled with the sharing of common risk factors, has given rise to the proposal of an asthma-obesity relationship (Tantisira & Weiss, 2001). In fact, many authors suggest that overweight and obesity increase the risk of asthma development (Gennuso *et al.*, 1998; Figueroa-Munoz *et al.*, 2001; von Kries *et al.*, 2001; Gilliland *et al.*, 2003; Bibi *et al.*, 2004; Oddy *et al.*, 2004; Schaub & von Mutius, 2005; Wickens *et al.*, 2005). Therefore, advancing the description of this association may significantly contribute to our understanding of the etiology of childhood asthma.

The results of the current study support the contention that a link exists between the asthma and obesity conditions. According to the gender- and age-specific cutoff points of Cole *et al.* (2000) and Taylor *et al.* (2002), 30.4% and 40.8% of asthmatic children/adolescents were deemed to be overweight or obese in terms of the BMI and %BF classifications, respectively. The prevalence rates were more pronounced in asthmatics than in the non-asthmatic youth reported in Chapter 3 of this work [21.1% using BMI cutoff points (Cole *et al.*, 2000) and 33.3% using %BF cutoff points (Taylor *et al.*, 2002)] or than in other recent data for non-asthmatic children in Australia (Booth *et al.*, 2001; Hesketh *et al.*, 2004). But more importantly, when combing grade and gender groups, asthmatic participants were almost twice as likely to be obese and 1.62 times more likely to be overweight (according to the BMI classifications of Cole *et al.*, 2000) when compared to the non-asthmatic cohort (see Tables 4.37 & 4.38). When expressed as a function of %BF category (Taylor *et al.*, 2002), asthmatic participants were 5.4 times more likely to be obese and 1.2 times more likely to be overweight than their non-asthmatic counterparts (see Tables 4.37 and 4.38).

Several specific mechanisms associate asthma and obesity including mechanical effects, up-regulated immune responses and fetal programming. Firstly, an elevated abdominal content, exemplified by obesity, can result in a reduced functional residual capacity due to the abnormal positioning of the diaphragm (Pelosi *et al.*, 1998; Gibson, 2000) and a reduced tidal volume (Sampson & Grassino, 1983). These effects resulted in the proposal of a smooth muscle 'latching' state in which rapidly cycling actin-myosin cross bridges are believed to be converted to slowly cycling latch bridges. (Fredberg *et al.*, 1996; Fredberg *et al.*, 1997; Fredberg, 2000). Specifically, a reduction in functional residual capacity and tidal volume are thought to reduce the amount of muscle strain occurring with each breath. This would cause fewer detachments of myosin from actin and result in stiffer airway smooth muscle. Hence, less airway smooth muscle shortening is predicted to result in reductions in airway calibre (Fredberg *et al.*, 1996; Fredberg *et al.*, 1997; Fredberg, 2000). In addition, the latch state is believed to contribute to increased airway hyper-responsiveness (Fredberg *et al.*, 1996; Fredberg *et al.*, 1997). Second, the prevalence of gastro-esophageal reflux in asthmatic children is around 50-60% (Sontag, 2000), while obesity has been cited numerous times as an independent risk factor for gastro-esophageal reflux and gastro-esophageal reflux symptoms (Locke *et al.*, 1999; Ruhl & Everhart, 1999; Wilson *et al.*, 1999). Gastro-esophageal reflux related asthma symptoms are thought to be a result of acid-induced bronchoconstriction; either by direct microaspiration or by vagally mediated reflux (Patterson & Harding, 1999), while gastro-esophageal reflux in obesity is believed to be mediated via increased abdominal pressures which increase the gastro-esophageal pressure gradient (Mercer *et al.*, 1987; Zacchi *et al.*, 1991). As a result, gastro-esophageal reflux has been hypothesized as a mediating factor in the relationship between asthma and obesity (Dixon *et al.*, 1999; Dhabuwala *et al.*, 2000). Third, an overlap of key genes may be involved in asthma and obesity. Specifically, tumour necrosis factor alpha (TNFα), interleukin 6 (IL-6) and interleukin 1β (IL-1β) have all been associated with the obese state (Hotamisligil *et al.*, 1995; Bunout *et al.*, 1996; Bastard *et al.*, 1999; Visser *et al.*, 1999; Visser *et al.*, 2001). Although the study by Visser *et al*. (2001) is the only paediatric study listed here, the associations between obesity, TNFα, IL-6 and IL-1β may be a consequence of childhood obesity. Elevated levels of circulating TNFα (Gosset *et al.*, 1992), and IL-6 production (Gosset *et al.*, 1992; Yokoyama *et al.*, 1995) have been reported in asthmatics and IL-1β has been associated with increased levels of IL-5, one of the primary cytokine mediators of asthma (Tang *et al.*, 1999).

It has also been postulated that similar *in utero* conditions may play a role in the development of asthma and obesity. A low birth weight has been associated with increased body fat later in life (Law *et al.*, 1992; Hediger *et al.*, 1998) and reduced adult lung function (Barker *et al.*, 1991). Furthermore, a small lung size is a known risk factor for asthma (Gold *et al.*, 2003), and obese mice reportedly have significantly smaller lung mass when compared to age- and gender-matched lean mice (Shore *et al.*, 2003).

Another major finding in this study is that neither asthma status (i.e. asthmatic vs. non-asthmatic) nor asthma severity (i.e. asthmatic participants stratified according to the asthma severity scale (Rosier *et al.*, 1994)) significantly influenced aerobic fitness or participation in physical activity. In addition, the current aerobic fitness findings compare favourably with those of several other studies of asthmatic children (Fink *et al.*, 1993; Thio *et al.*, 1996; Santuz *et al.*, 1997) and non-asthmatic children alike (see Tables 1.3 & 3.22). Specifically, Thio *et al*. (1996) reported a mean peak $\dot{V}O_2$ of 48.4 $ml.kg^{-1}.min^{-1}$ for 16 children aged 10.3 ± 1.7 years, while Fink *et al*. (1993) reported 43.4 ± 8.4 $ml.kg^{-1}.min^{-1}$ for 16 children aged 10.3 ± 1.7 years, and Santuz *et al*. (1997) reported 45.5 ± 8.4 $ml.kg^{-1}.min^{-1}$ for 19 children aged 12 ± 2 years, which are all in agreement with the current findings. This is an important finding as it provides evidence that asthmatic children and adolescents are capable of (i) undertaking physical activity unhindered by their disease and (ii) achieving comparable levels of aerobic conditioning as non-sufferers. In fact, the similar aerobic fitness levels between participants of differing asthma status and severity highlights that the trainability of the cardio-respiratory system in asthmatics is unimpaired.

The data contained in this chapter further demonstrate that asthmatic children and adolescents who are pre-medicated with a bronchodilator prior to exercise do not appear to have any added functional limitation as a result of their disease, regardless of severity, thereby not experiencing restrictions to their physical activity involvement, fitness development or trainability. However, the small number of severely asthmatic children and the degree of asthma severity among the participants in this study may have played a role in the lack of differences observed for aerobic fitness and physical activity when compared to the non-asthmatic data from Chapter 3. Generally, the mean ASQ values for all groups fell into the *mild* severity range (except for Grade 8 females whose mean was in the *moderate* range – see Table 4.5), with only 10.4% of participants classified as *severe* compared to

67.2% in the *trivial-mild* category and 22.4% classified as *moderate* sufferers (see Table 4.6 and Figure 4.2). It should be noted, however, that high levels of fitness may have played a role in the lack of association between asthma severity and aerobic fitness/physical activity. More specifically, the sensation of respiratory symptoms, and their report, may be influenced by a person's fitness. A high level of fitness was suggested to raise a person's 'threshold' to respiratory symptoms and raise the level at which respiratory discomfort develops (Clark, 1992), with the mechanism proposed to be alterations in brain ventilatory chemosensitivity (Mahler *et al.*, 1989).

Interestingly, Pianosi and Davis (2004) suggest that aerobic power among asthmatic children is related more so to how capable children perceive themselves than to their actual asthma severity. While Pianosi and Davis (2004) highlighted that the estimation of asthma severity was a troublesome task, they reported that the strongest association with aerobic fitness was with the psychological predictors of athleticism, including perceived competence at physical activity and attitudes toward physical activity involvement, but not asthma severity. Despite these findings, it is reasonable to suggest that if the asthmatic condition was ever to be a deterrent to physical activity involvement or a cause of reduced capacity for exercise, it would reveal itself at the *severe* end of the spectrum. However, the small sample size of asthmatics in the *severe* category precludes generalisations about any deficits in physical activity and/or aerobic fitness that may exist for children and adolescents who suffer severe cases of the disease.

The similar 6MR distances covered across asthma severity classifications may also, in part, be a reflection of the anti-asthma medication administered prior to the 6MRT. Exercise in adult asthmatics without prior treatment can increase ventilation-perfusion mismatching, alveolar-arterial oxygen tension difference and physiologic dead space (Anderson *et al.*, 1972) however, these effects seem to be minor if standard medications are used pre-exercise (Freeman *et al.*, 1989). In addition, the lack of difference among severity groups in spirometric indices in the present study (see Table 4.4 and Figure 4.1) suggest that maximal voluntary ventilations throughout exercise would not be dissimilar between participants.

The impact that asthma has on aerobic fitness and physical activity across the complete severity range remains unresolved. This fact may also help to explain the variability and inconsistency in the literature concerning the presence of a deficit in aerobic fitness in the paediatric asthmatic population (see review by Welsh *et al.*, 2004).

The equivocal nature of previous work focusing on aerobic fitness in asthmatic youth results in the identification of three key areas most likely contributing to discrepancies in the outcomes; namely (i) sample selection, (ii) methodological variations, and (iii) statistical analysis. The majority of studies in which aerobic fitness was measured via indirect calorimetry have cited relatively small sample sizes (Bevegård *et al.*, 1971; Hedlin *et al.*, 1986; Varray *et al.*, 1989; Thio *et al.*, 1996; Boas *et al.*, 1998; Counil *et al.*, 2001), while the larger field studies have not always compensated for the increased variability of their samples (Fink *et al.*, 1993; Santuz *et al.*, 1997). Non-asthmatic control groups are infrequently randomly selected and the gender and age distribution in these groups are poorly matched to asthmatic cohorts (Bevegård *et al.*, 1971; Hedlin *et al.*, 1986; Strunk *et al.*, 1988; Fink *et al.*, 1993; Kukafka *et al.*, 1998). Furthermore, few studies have investigated the full range of asthma severity in a single study (Bevegård *et al.*, 1971), and the majority of the literature is focused on paediatric samples suffering mild and moderate asthma (Ram *et al.*, 2000; Satta, 2000; Welsh *et al.*, 2004; Welsh *et al.*, 2005). Intuitively, testing asthmatic children with and without pre-medication affects peak $\dot{V}O_2$ scores; however, perhaps because of ethical constraints, no such study addresses this question. Finally, some studies have not used appropriate statistical analyses, thereby limiting the validity of the conclusions (Hedlin *et al.*, 1986; Wong *et al.*, 2001).

The similarities in aerobic fitness between asthmatic and non-asthmatic participants in this study agree with the similarities found in physical activity between the two groups. However, such similarities may not continue into adulthood. Asthma status may begin to influence physical activity as asthmatics mature, from later adolescence into adulthood, as suggested by two adult studies reporting significant deficits in physical activity for asthmatic individuals compared to age-matched non-asthmatic controls (Mälkiä & Impivaara, 1998; Ford *et al.*, 2003). However, asthma phenotype was suggested to change from childhood to adolescence and, therefore, physical activity differences may only be observed in specific age groups and in certain groups of asthmatics (Clough, 1998). Longitudinal studies of asthmatic physical activity habits would likely elucidate whether such a phenomenon exists.

Significant inverse associations existed between aerobic fitness and measures of body composition in the asthmatic cohort, in agreement with that reported for non-asthmatics in

Chapter 3. Although significant positive associations existed between PAQ-C and aerobic fitness values, grouping participants according to grade and gender revealed an inverse association between aerobic fitness and body fat that could not be attributed to physical activity. Specifically, PAQ-C and activity monitor counts were similar between BMI and %BF stratifications for the asthmatic group (Tables 4.30 & 4.32), with regression analyses supporting these outcomes. Furthermore, neither peak heart rate responses (Tables 4.22 & 4.24) nor estimated energy expenditure values (Table 4.26) could explain the lower aerobic fitness levels in overweight and obese asthmatics.

That neither aerobic fitness nor physical activity differences (when compared to non-asthmatics) could explain the greater prevalence of overweight and obesity in the asthmatic cohort implies that other factors must be responsible for excessive body fatness. It has previously been reported that obesity can cause dyspnoea through mechanisms other than airflow obstruction, including increased work of breathing and deconditioning (Martinez *et al.*, 1994; Schachter *et al.*, 2001; Sin *et al.*, 2002), as well as obstructive sleep apnoea (van Boxem & de Groot, 1999). Therefore, it is possible that some overweight and obese participants in the current sample may have previously been misclassified as asthmatic. However, given the possible biological mechanisms by which obesity could be expected to either cause or worsen asthma, including gastro-esophageal reflux, complications from sleep-disordered breathing, breathing at low lung volume and chronic systemic inflammation (Gennuso *et al.*, 1998; Figueroa-Munoz *et al.*, 2001; von Kries *et al.*, 2001; Gilliland *et al.*, 2003; Bibi *et al.*, 2004; Oddy *et al.*, 2004; Schaub & von Mutius, 2005; Wickens *et al.*, 2005), the greater incidence of overweight and obesity in this paediatric sample is not likely to be a case of misdiagnosis.

The absence of any association between asthma severity and body composition reported here is in agreement with previous work focused on asthma severity, overweight and obesity (Gennuso *et al.*, 1998; Tantisira *et al.*, 2003). However, others have described overweight as being associated with significantly more severe asthma symptoms (Luder *et al.*, 1998; Wickens *et al.*, 2005). Given that each of these studies used BMI to assess body composition, differences in definitions of asthma severity may be responsible for the discrepancies in the literature.

**Normative Data**

***Body Composition***

Younger participants had significantly lower mean BMI values when compared to older participants and grade 5 and 8 males had significantly lower %BF when compared to females of the same age. These results are consistent with the grade and gender differences reported for non-asthmatic participants in Chapter 3 and are also consistent with the well-established age and gender differences expected in BMI and %BF (Malina *et al.*, 1988; Guo *et al.*, 1992; Boot *et al.*, 1997; Nagy *et al.*, 1997; Taylor *et al.*, 1997; Mast *et al.*, 1998). The gender differences in body fat were again independent of body mass due to no differences being found between genders of the same age (see Table 4.1).

Applying the BMI cutoff points of Cole *et al.* (2000) revealed that mean BMI values for each grade and gender group fell within the normal healthy range, consistent with the non-asthmatic results reported in Chapter 3. The %BF cutoff points of Taylor *et al.* (2002) showed that grade 5 participants were on the cusp between the normal and overweight %BF ranges, whereas grade 8 participants were within the normal healthy %BF range. By contrast, each non-asthmatic grade and gender group was within the normal healthy %BF range.

***Aerobic Fitness***

Males recorded significantly greater mean 6MRD and predicted peak $\dot{V}O_2$ values when compared to females of the same age. Furthermore, grade 5 participants had significantly greater mean 6MRD/FFM values when compared to grade 8 participants. These age and gender differences agree with the non-asthmatic findings reported in Chapter 3. A greater muscle mass in males (Malina *et al.*, 2004), the degree of body fat accumulation among females during maturation (Malina *et al.*, 1988; Guo *et al.*, 1992) and consistent declines in physical activity throughout the school age years (Sallis, 1993) are all possible reasons for the observed differences. However, the effect that physical activity on aerobic fitness in youth is debatable (Morrow & Freedson, 1994).

The predicted aerobic fitness results are consistent with the non-asthmatic results described in Chapter 3 (see Table 4.10, Appendix M: Chapter 4 Appendices) as well as asthmatic children from other countries (Fink *et al.*, 1993; Thio *et al.*, 1996; Santuz *et al.*, 1997). Moreover, the current 6MRD results are consistent with the findings of a comparable study of 66 Melbourne school boys (aged 10 to 14 years), which reported mean 6MRD values of

1066.6 ± 148.1 m and 1276.5 ± 69.8 m for non-asthmatic grade 5 (n= 40) and 8 males (n=17), respectively, and mean 6MRD values of 1108.3 ± 114.1 m and 1203.3 ± 120.8 m for grade 5 (n=6) and 8 (n=3) asthmatic males, respectively (Toohey, 2000). In addition, Bate (2001) reported mean 6MRD values of 1021 ± 128.5 m and 1046.5 ± 128.6 m for grade 5 and 8 girls, respectively, in a study of 59 non-asthmatic school girls (aged 10 to 14 years) from Melbourne, Australia.

***Physical Activity***

Grade 5 participants recorded significantly greater mean estimated MET values when compared to grade 8 participants, and the younger male group also recorded a significantly greater mean PAQ-C value when compared to their older counterparts. These age differences in physical activity are consistent with the literature for non-asthmatic children (Crocker *et al.*, 1997; Crocker *et al.*, 2000). In comparison with the non-asthmatic PAQ-C values reported in Chapter 3, one significant difference existed; that grade 5 asthmatic females recorded a significantly lower PAQ-C value when compared to grade 5 non-asthmatic females. Given no other significant differences were found, this result is likely a reflection of the difficulties associated with young children accurately recalling their physical activity (Baranowski & Simons-Morton, 1991; Sallis *et al.*, 1996). Males posted significantly greater mean PAQ-C values when compared to females of the same age, which is also in agreement with the non-asthmatic data reported in Chapter 3 and is consistent with the established non-asthmatic literature (Crocker *et al.*, 2000). In comparison with the only other asthmatic study to employ the PAQ-C, Toohey (2000) reported mean PAQ-C values of 3.39 ± 0.38 and 3.03 ± 0.59 for grade 5 and 8 asthmatic males, respectively. Furthermore, the current mean PAQ-

C scores also agree with those of non-asthmatic studies highlighted in Chapter 3 (Crocker *et al.*, 1997; Crocker *et al.*, 2000; Toohey, 2000; Bate, 2001). No significant differences were found in activity monitor counts or estimated MET values between the current asthmatics and non-asthmatics described in Chapter 3 (see Table 4.13), and there were no grade or gender differences in terms of the time spent in the various physical activity intensity ranges (see Table 4.12).

**Concluding Remarks**

Neither asthma status (i.e. asthmatic versus non-asthmatic) nor the degree of asthma severity significantly influenced aerobic fitness or involvement in daily physical activity. That is, asthmatic participants achieved comparable levels of aerobic fitness and recorded similar levels of physical activity when compared to their non-asthmatic counterparts. Moreover, no differences existed in aerobic fitness or physical activity on account of disease severity. These results indicate that trivial, mild and moderate asthma should not limit a child's physical activity involvement, trainability, or ability to achieve a high level of aerobic fitness. However, it remains unclear whether any deficits in physical activity or aerobic fitness are present among severe sufferers, given the low number of severely asthmatic participants.

The asthmatic condition was associated with a greater prevalence of overweight/obesity than the prevalence reported for the non-asthmatic participants in the previous chapter. In fact, asthmatic participants were up to 5.4 times more likely to be obese than non-asthmatic participants when body composition category was assessed by the %BF cutoff points of

Taylor *et al*. (2002) and almost twice as likely to be obese when assessed according to the BMI cutoff points of Cole *et al*. (2000). Asthmatic participants also demonstrated an inverse relationship between measures of aerobic fitness and markers of body fat, consistent with the non-asthmatic data reported in Chapter 3.

Therefore, these results emphasize the association between aerobic fitness and body composition, yet also indicate that asthma is a significant risk factor for overweight and obesity. Asthmatic children and adolescents should therefore aim to attain their best possible aerobic fitness level, in order to optimise asthma management and to reduce their likelihood of becoming overweight or obese.

# Chapter 5 Peak Oxygen Consumption, Physical Activity and Body Mass Index in Severely Asthmatic Children and Adolescents

## 5.1 Introduction

Among children and adolescents, asthma severity can be assessed in several ways. Aside from clinical assessment (Chapter 1 - Section 1.3.4), other methods include lung function testing, exercise-induced bronchoconstriction (occurrence and degree), daily asthmatic symptoms, medication habits, number of wheeze attacks and hospitalisations, as well as parental opinion. The classifying of asthma severity can often make comparisons across studies difficult. What is clear however, is that regardless of the definition used, the *severe* end of the disease spectrum, particularly among children, is under-represented in the literature addressing asthma-related physical activity and aerobic fitness. The bulk of the literature on aerobic fitness and physical activity in asthmatic children relates to the mildly and moderately affected group of asthmatic children (Ram *et al.*, 2000; Satta, 2000; Welsh *et al.*, 2004; Welsh *et al.*, 2005).

The degree of resting airway obstruction in asthmatic children and adolescents is likely to be at its greatest in severe sufferers, and may significantly influence the ventilatory limitation to exercise (Babb *et al.*, 1991). Together with this, the degree of bronchial hyper-responsiveness may also limit exercise tolerance, producing a ventilatory endpoint rather than a physiologic cardiovascular endpoint (Fairshter *et al.*, 1989; Anderson, 1993). Such limitations are typically associated with unpleasant dyspnoea and could result in severely asthmatic children avoiding exercise. Compounding this problem is the suggestion that a diagnosis of asthma may consciously or unconsciously lead parents to restrict their child's physical activity in order to avoid exacerbating symptoms (Firrincieli *et al.*, 2005). Intuitively, severe asthmatics are most likely to be restricted in the presence of such phenomena. This may contribute to the small number of severely asthmatic participants giving their consent to participate in the field studies undertaken in Chapter 4, yet, it is in this group that such a ventilatory limitation to exercise would most likely be seen (Lewis *et al.*, 1994; Satta, 2000).

Children and adolescents regularly participate in physical activity to maintain their health (Olds *et al.*, 2004). However, a chronic avoidance of exercise in a severely asthmatic child is likely to result in physical deconditioning, and may increase the number and intensity of wheezing attacks, as well as increase medication usage, hospitalisations, and doctor consultations (Sly *et al.*, 1972; Huang *et al.*, 1989; Engstrom *et al.*, 1991; Wardell & Isbister, 2000). In addition, a persistent lack of exercise involvement may also heighten the risk of an asthma attack during exercise (Henriksen *et al.*, 1981; Henriksen & Nielsen, 1983) and worsen asthma control. Conversely, a greater level of aerobic fitness would likely result in greater maximum exercise breathing capacity and, hence, attenuate the distress associated with exercise-induced bronchoconstriction or an asthma attack and improve asthma management (Ramazanoglu & Kraemer, 1985; Szentagothai *et al.*, 1987; Huang *et al.*, 1989; Engstrom *et al.*, 1991; Ram *et al.*, 2005; Welsh *et al.*, 2005).

A paucity of cross-sectional investigations have included a focus on the aerobic fitness levels of severely asthmatic children and adolescents, and studies in which fitness was included, have displayed a lack of agreement. Bevegård *et al.* (1971) concluded that "even children with severe asthma have a normal maximal oxygen uptake capacity" and Pianosi *et al.* (2004) reported similar peak $\dot{V}O_2$ values for mild, moderate and severe sufferers. Conversely, Fink *et al.* (1992) reported significantly reduced $\dot{V}O_{2max}$ among severe asthmatics when compared to non-asthmatic controls whilst Strunk *et al.* (1988) reported that 91% of moderate and severe asthmatic children performed below the 50$^{th}$ percentile in a 9-minute run. However, bronchodilator medication prior to exercise challenge testing has been administered in some studies (Pianosi *et al.* 2004, Strunk *et al.* 1988) but not others (Bevegård *et al.*, 1971; Fink *et al.*, 1992). Moreover, several physical conditioning studies of severely asthmatic youth have not included a non-asthmatic control group (Nickerson *et al.*, 1983; Ludwick *et al.*, 1986; Engstrom *et al.*, 1991) and, therefore, it remains unclear whether severe asthmatics have an added ventilatory limitation to exercise.

Most paediatric studies focusing on physical activity fail to demonstrate a deficit in the physical activity levels in asthmatic children (Weston *et al.*, 1989; Nystad, 1997; Chen *et al.*, 2001; Wong *et al.*, 2001; Pianosi & Davis, 2004). Lang *et al.* (2004) and Firrincielli *et al.* (2005) reported physical activity deficits among asthmatics, with Lang *et al.* (2004) being one of only two studies to include a severely asthmatic group (the other being Pianosi *et al.* (2004)). Moreover, physical activity was estimated by questionnaire in all but one of the aforementioned studies (Firrincielli *et al.* (2005) assessed physical activity via a wristwatch accelerometer - Actiwatch®). The validity of physical activity questionnaires completed by parents or children has been questioned when compared to objective measures of physical activity such as accelerometry (Welk *et al.*, 2000), and children have previously displayed difficulty with accurately recalling their physical activity habits (Baranowski & Simons-Morton, 1991; Sallis *et al.*, 1996). Therefore, the paucity of data derived from objective measures of physical activity in the asthmatic population, especially among those severely affected, highlights the need for greater objectively-derived data to support (or otherwise) the current views about physical activity in this population.

Increases in asthma prevalence over recent decades (Magnus & Jaakkola, 1997) are mirrored by increases in the prevalence of obesity (Magarey *et al.*, 2001). This has prompted an upsurge in research focusing on the interaction between asthma and obesity, with several groups supporting an association between the two morbidities (Tantisira & Weiss, 2001; Ford, 2005; Shore & Johnston, 2006). Subsequently, excess body fatness is another factor that may play a role in the physical activity and aerobic fitness levels of severely asthmatic children. This concept is supported by the proportion of asthmatic participants described in the previous chapter who demonstrated an inverse association between measures of aerobic fitness and markers of increased body fat. Moreover, obesity can result in a reduced functional residual capacity, a condition which alone can heighten the bronchial hyper-responsiveness of non-asthmatics (Chinn *et al.*, 2002). Therefore, the bronchial hyper-responsiveness present in the airway of a severely asthmatic child may be heightened by excess body fatness and could consequently limit their exercise tolerance (Anderson, 1993).

Overall, it remains unclear whether severely asthmatic children and adolescents have a deficit in terms of their physical activity and aerobic fitness levels, with the possibility that body composition differences may exacerbate any deficits. A clearer understanding of these relationships would assist clinicians in delivering more efficacious asthma management strategies. For these reasons, the aim of the current chapter is to ascertain whether a ventilatory limitation to exercise and/or an altered physical activity participation is present in severely asthmatic youth. Moreover, this study also aims to determine whether overweight and obesity is more likely in this group in comparison to less severe asthmatics and non-sufferers.

## 5.2 Methodology

### 5.2.1 Participants

Severely asthmatic participants, aged 10 to 16 years, were recruited from the Respiratory Outpatient clinic at the Royal Children's Hospital, Melbourne. On the advice of paediatric respiratory consultant physicians, participants were classified as severely asthmatic if they required 500µg of steroid therapy per day.

### 5.2.2 Procedure

Testing occurred in the Respiratory Laboratory at the Royal Children's Hospital, Melbourne. Height was recorded, with the participant not wearing shoes, to the nearest 0.1 cm using a fixed stadiometer (Magnimeter, Raven Equipment Ltd, Essex, England). Body mass was measured in minimal clothing, without shoes, to the nearest 0.1 kg using digital scales (Tanita BWB 600, Tanita Corp, Tokyo). All participants were then medicated with 800µg of Ventolin™ (Salbutamol) via a Volumatic™ spacer and metered dose inhaler (Allen &

Hanburys, Uxbridge, United Kingdom). Participants then completed the PAQ-C (Crocker *et al.*, 1997) in the time period after receiving bronchodilator medication and prior to the graded exercise test (GXT). The PAQ-C was administered using the same protocol employed for 'school-tested' participants. Spirometry was performed by participants at 10 to 15 minutes post-bronchodilator to ensure eligibility to complete the GXT [that is, $FEV_1$ % predicted was required to be equal to or greater than 75% of predicted normal (Anderson, 1993)]. Spirometry was conducted using a Jaeger MasterScreen® Body plethysmograph running software version 4.35 (Jaeger, Würzburg, Germany) – see Figure 5.1. The same protocol used for the 'school-tested' participants (Section 2.2.3) was employed to test spirometry in the 'laboratory-tested' participants (American Thoracic Society, 1995). The spirometer was calibrated daily using a Hans Rudolph 3-litre syringe (Hans Rudolph Inc, Kansas City, Missouri, USA) with an acceptable error defined as <1%. Participants then completed the GXT procedure. In preparation for the GXT, participants were instructed to wear comfortable clothing and running shoes suitable for exercise. In addition, participants were asked to refrain from eating for at least two hours prior to arrival and to avoid strenuous exercise for at least 24 hours preceding the GXT. The GXT was performed on an Austradex Model AC489 treadmill (Emmans & Sons, Preston, Victoria, Australia) using Oxycon Record software (Jaeger, Würzburg, Germany) for respired gas analysis. Volume was measured using a low resistance, low dead space (30 ml) Oxycon Triple V valve and transducer which was connected to a Hans Rudolph 2700 series one-way valve (Hans Rudolph Inc, Kansas City, Missouri, USA), a snorkel-style mouthpiece and a 'dry air' gas supply.


**Figure 5.1 Jaeger MasterScreen® Body plethysmograph**

The MasterScreen® Body plethysmograph can be used for comprehensive differential diagnosis, and allows for the detection of restrictive and/or obstructive ventilatory disorders. The air-tight plethysmograph consists of a heated pneumotachograph including a pressure transducer. The plethysmograph shown is connected to a personal computer (off left of picture) for the measurement, evaluation, storage and documentation of spirometric indices, including FVC and $FEV_1$. The MasterScreen® Body plethysmograph has a flow range of 0 - 20 litres per second and a volume range of 0 - 20 litres per second with volume accuracy of ± 3%.

Equipment was checked and calibrated prior to and immediately following each test. Specifically, the gas analyser system was calibrated before each test with a beta standard calibration gas ($O_2$: 16.3 ± 0.2%; $CO_2$: 5.1 ± 0.10%; Balance: Nitrogen), the composition of which had been previously validated against an alpha standard gas mixture. The volume transducer was calibrated using a Hans Rudolph 2-litre syringe (Hans Rudolph Inc, Kansas City, Missouri, USA). Expired gas was analysed by a fast response differential paramagnetic oxygen analyser to measure oxygen concentration and an infra-red analyser to measure carbon dioxide concentration. The breath-by-breath data were displayed and averaged over five breaths with the data printout displaying 10-second averaged data. Prior to the commencement of testing, the GXT procedure was explained to the participant and (if present) the parent, stressing that the challenge would involve strenuous exercise lasting at least eight minutes. It was also explained that sensations such as shortness of breath (dyspnoea), tiredness and muscle fatigue were 'normal'. Although the participant was informed that the GXT would be terminated at any such time that they chose not to continue, it was emphasized that the data collected throughout test would be of 'most' use if the participant worked to near maximal capacity by the end of the test. After participants had completed spirometry testing, maximal voluntary ventilation (MVV) was estimated as $FEV_1$ predicted x 35 (Woolley *et al.*, 1990; Anderson *et al.*, 1991; Anderson *et al.*, 2001). The target minute ventilation ($\dot{V}E$) was then set at 60% MVV. From here, the predicted $\dot{V}E$ values for each minute of the GXT were calculated and recorded on the test data sheet (Appendix G), with the first minute calculated as 60% of the target, the second minute at 75%, the third at 90%, and the remainder of the test at 100%. In addition, target heart rate responses were greater than 85% of the participant's predicted maximal heart rate (West *et* *al.*, 1996), where predicted maximal heart rate was calculated as 210 – (0.65*age) (Spiro, 1977). Throughout the GXT, the attainment of these target values was a priority to ensure that maximal efforts were achieved. A final inspection of the GXT equipment was carried out, ensuring that the inspiratory valve and Triple V valve with mouthpiece, volume transducer and end tidal line were all in place and functioning correctly. Following this, the electrodes of the Polar® Vantage NV heart rate monitor transmitter (Polar Electro Oy, Kempele, Finland) were moistened with warm water (to aid signal transmission) and fitted around the participant's chest, ensuring a firm connection. A Nellcor N200 pulse oximeter probe (Nellcor Inc., Pleasanton, California) was attached to the middle finger of the participant's left hand, with checks made to ensure that a reliable and consistent output was displayed on the oximeter's monitor. Baseline heart rate and oxygen saturation data were subsequently recorded. The participant was then instructed to stand on the treadmill to permit the height of the mouthpiece and valve to be adjusted accordingly. At this time, participants also became familiar with breathing through the mouthpiece. A clip was placed on the nose to occlude it completely. With the participant standing and breathing through the mouthpiece, the treadmill was started at a slow speed (3-4 km/hr) while the participant became familiar with walking on the moving belt. Once the gradient of the treadmill was raised to 10% and the initial target speed was reached (determined from size, age and apparent degree of physical fitness), participants were instructed to let go of the handrails and the timed portion of the GXT began. Heart rate and oxygen saturation were recorded each minute. In accordance with the American Thoracic Society's recommendations for exercise testing, treadmill speed was increased each minute for the first four minutes of the GXT and then both gradient and speed were adjusted accordingly to achieve around four to six minutes of exercise at near-maximum targets and achieve peak aerobic power (i.e. 8-10 minutes of exercise in total). The GXT was terminated at the point of voluntary exhaustion, when the participant was unable to continue despite strong verbal encouragement. The experienced laboratory scientists who supervised the GXT were adequately trained in testing and emergency procedures and at all times monitored the patient for any signs of undue stress (e.g. severe wheezing, chest pain, lack of coordination, marked decrease in oxygen saturation). The fulfillment of at least three of the following four criteria was required to meet the definition of a 'maximal' exercise test: 1) a maximal heart rate similar to the theoretically predicted maximal value; 2) a peak $\dot{V}E$ close to the predicted target; 3) a plateau in oxygen uptake despite an increasing workload (i.e. final increase in $\dot{V}O_2 < 200$ $ml.min^{-1}$ for an increase in work of 5 to 10%); 4) an inability of the participant to maintain the treadmill speed despite encouragement (Crapo *et al.*, 2000; Wasserman *et al.*, 2005). An example of the data and graphical representations generated from the GXT are shown in Appendix H. Figure 5.2 displays a selection of photographs with participants performing the GXT. Following the GXT for those participants who consented, a programmed activity monitor was fitted according to the procedure described in Section 2.2.5 prior to departing the Respiratory Laboratory.

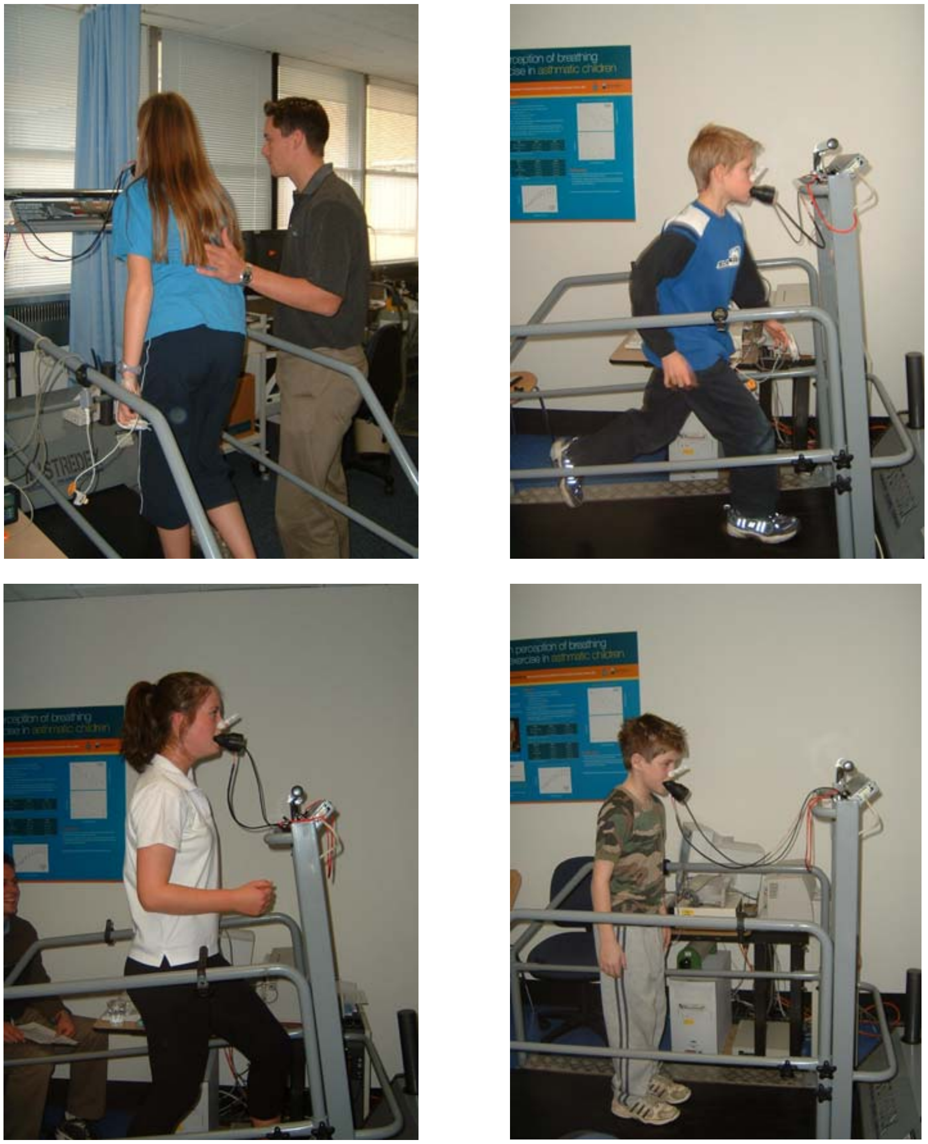


**Figure 5.2 Severely asthmatic participants performing a maximal graded exercise test.**

Graded exercise tests were performed using an Austradex Model AC489 treadmill using Oxycon Record software. Volume was measured using an Oxycon Triple V valve and transducer connected to a Hans Rudolph 2700 series one-way valve, and a snorkel type mouthpiece with a 'dry air' gas supply. Heart rate responses were recorded using a Polar® Vantage NV heart rate monitor and oxygen saturation was monitored with a Nellcor N200 pulse oximeter. Participants performed at least 8 minutes of strenuous exercise and were pre-medicated with 800µg of Ventolin™ (Salbutamol).

### 5.2.3 Data Management

Data were grouped according to gender. Physical activity and aerobic fitness data were stratified according to BMI category (Cole *et al.*, 2000) to determine the influence of body composition. Activity monitor counts were converted to estimated estimated MET values and the time representation for each intensity range was also calculated (Trost, 2001). PAQ-C and activity monitor data were analysed in the same manner as described in Section 2.2.5.1.

### 5.2.4 Statistical Analysis

Statistical analysis was performed using *Stata* Version 8.0 (Stata Corporation, Texas, USA). The one-sample Kolmogorov-Smirnov test was employed to test the normality of each data variable. All descriptive data were reported as mean and standard deviation. Unpaired *t* tests were used to test if population means estimated by two independent samples differed significantly. This included, for example, comparing mean values of severely asthmatic participants according to gender. Regression analyses were performed to estimate the predictive power of an independent variable (or a group of independent variables) on a dependent variable, such as peak $\dot{V}O_2$. Correlation analyses were also performed to determine the interdependence of two variables. Significance levels were set at $p<0.05$. Odds ratios were employed to estimate the association between asthma and markers of body fat. Specifically, odds ratios were calculated for each gender group within this chapter to determine whether severely asthmatic participants were more likely to be overweight or obese than the non-asthmatic participants described in Chapter 3 and the less severely asthmatic sufferers described in Chapter 4. In addition, Mantel-Haenszel estimates were calculated to determine overall odds ratios for male and female combined data. To provide non-asthmatic "control" group data for the GXT, non-asthmatic GXT data collected by colleagues at the Royal Children's Hospital, Melbourne, for two separate studies (Toohey, 2000; Bate, 2001) that acted as pilot testing for the work completed in this thesis, were utilised. Severely asthmatic GXT data were compared to non-asthmatic GXT data using unpaired *t* tests.

## 5.3 Results

### 5.3.1 Participants

Thirty-two severely asthmatic children and adolescents were recruited from the Respiratory Outpatient clinic at the Royal Children's Hospital, Melbourne. All participants completed the GXT protocol, with 16 being fitted with an activity monitor for a seven-day period. No differences were found between males and females in terms of mean age, height, mass, BMI or post-bronchodilator spirometric indices (Table 5.1). $FEV_1$ % predicted was within the normal healthy range (Zapletal *et al.*, 1987) for all participants.

**Table 5.1 Severely asthmatic participant characteristics**

| | **Male** (n = 19) | **Female** (n = 13) | **Total** (n = 32) |
|---|---|---|---|
| **Age (years)** | 11.12 ± 2.56 | 12.01 ± 2.10 | 11.50 ± 2.4 |
| **Height (cm)** | 145.6 ± 14.9 | 147.7 ± 12.7 | 146.4 ± 13.9 |
| **Mass (kg)** | 43.3 ± 17.8 | 45.9 ± 11.5 | 44.4 ± 15.4 |
| **BMI ($kg/m^2$)** | 19.7 ± 4.4 | 20.6 ± 2.9 | 20.1 ± 3.8 |
| **$FEV_1$** | 2.24 ± 0.83 | 2.36 ± 0.63 | 2.30 ± 0.75 |
| **$FEV_1$ (% Predicted)** | 96.6 ± 16.6 | 102.0 ± 13.4 | 98.7 ± 15.3 |
| **FVC** | 2.55 ± 1.00 | 2.60 ± 0.70 | 2.60 ± 0.90 |
| **FVC (% Predicted)** | 93.3 ± 12.4 | 103.0 ± 17.1 | 97.2 ± 15.0 |
| **FER ($FEV_1$/FVC)** | 88.2 ± 8.8 | 90.2 ± 7.3 | 89.0 ± 8.1 |

Mean ± SD

## 5.3.2 Forced Expiration Ratio (FER) Comparison

Although $FEV_1$ and FVC were found to be within the normal healthy range (Zapletal *et al.*, 1987), the forced expiratory ratio (FER) was 3.9% lower (t[155]=2.32; p=0.02) in 'laboratory-tested' severe asthmatics when compared to 'school-tested' asthmatics and 4.1% lower (t[665]=3.15; p=0.001) than 'school-tested' non-asthmatics (Figure 5.3).

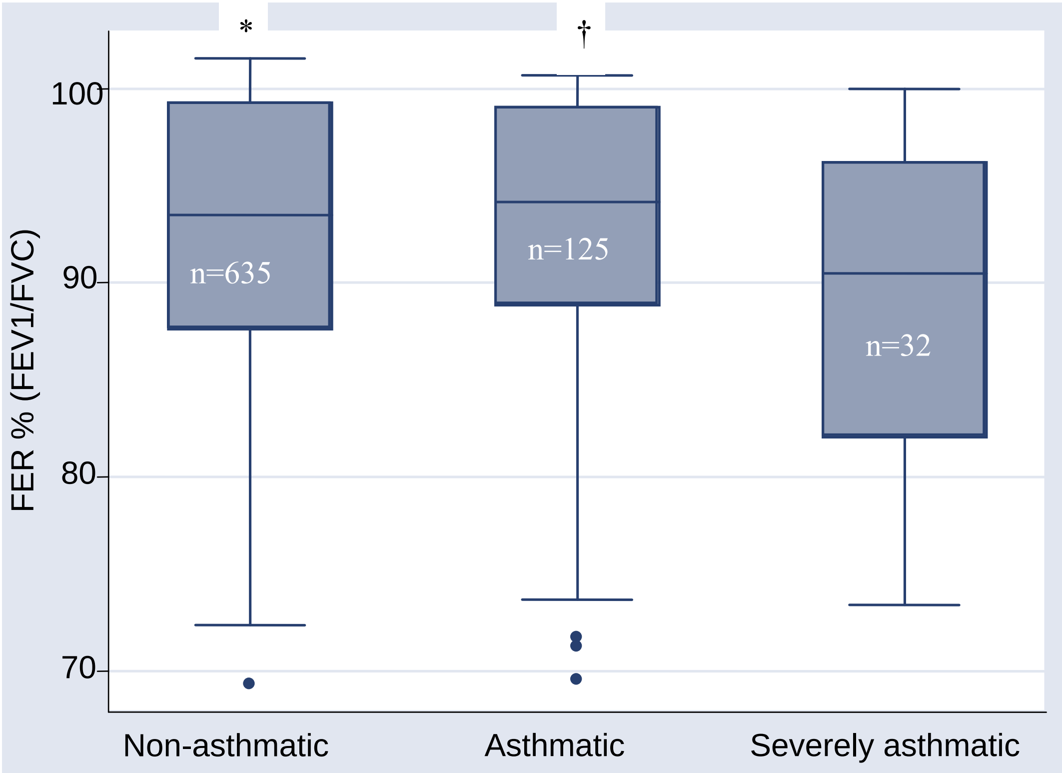



**Figure 5.3 Comparison of forced expiratory ratio values between 635 school-tested non-asthmatic children and adolescents aged 10-14, 125 school-tested asthmatic children and adolescents aged 10-14, and 32 laboratory-tested severely asthmatic children and adolescents aged 10-16 years.** Box-whisker plots show the mean and 95% confidence intervals. Outliers represent those values outside the 95% confidence interval.

FER = Forced expiratory ratio; $FEV_1$ = Forced expiratory volume in one second; FVC = Forced vital capacity.

* significantly different ($p<0.01$) from laboratory tested severely asthmatic participants

† significantly different ($p<0.03$) from laboratory tested severely asthmatic participants

### 5.3.3 Testing Data Distribution for Normality

Kolmogorov-Smirnov test results for age, height, body mass, heart rate, BMI, peak $\dot{V}O_2$, PAQ-C, activity monitor counts, $FEV_1$ % predicted and FVC % predicted variables are shown in Table 5.2 (Appendix N: Chapter 6 Appendices), confirming that all data sets were normally distributed.

### 5.3.4 Graded Exercise Test (GXT) Data

The GXT data for the 'laboratory-tested' participants are shown in Table 5.3. Of the sample (n=32), 29 participants achieved a peak heart rate above 90% of their predicted maximum. In addition, all 32 participants met the other criteria outlined in Section 2.4.4 for the attainment of a maximal test. No significant differences were found between males and females in terms of peak $\dot{V}O_2$ or peak heart rate. However, females recorded a 5% greater ($t[30]=2.22$; $p=0.03$) RER value compared to males.

**Table 5.3 Graded exercise test data at peak $\dot{V}O_2$ for 32 severely asthmatic participants**

| | **Male** (n = 19) | **Female** (n = 13) | **Total** (n = 32) |
|---|---|---|---|
| **$\dot{V}O_2$ (ml.min$^{-1}$)** | 1873.7 ± 730.0 | 1717.3 ± 491.0 | 1810.1 ± 639.4 |
| **$\dot{V}CO_2$ (ml.min$^{-1}$)** | 2046.2 ± 813.0 | 1972.4 ± 580.8 | 2016.2 ± 718.0 |
| **Respiratory exchange ratio ($\dot{V}CO_2$/$\dot{V}O_2$)** | 1.10 ± 0.10$^{\dagger}$ | 1.15 ± 0.10 | 1.12 ± 0.10 |
| **Peak $\dot{V}O_2$ (ml.kg$^{-1}$.min$^{-1}$)** | 45.3 ± 9.3 | 41.3 ± 5.9 | 43.7 ± 8.2 |
| **Heart Rate (bpm)** | 192.0 ± 6.3 | 191.0 ± 7.7 | 191.6 ± 6.8 |
| **Oxygen Pulse (ml.kg$^{-1}$.beat$^{-1}$)** | 0.23 ± 0.10 | 0.20 ± 0.04 | 0.22 ± 0.05 |
| **Oxygen Saturation (%)** | 96.4 ± 1.0 | 94.8 ± 1.7 | 95.6 ± 1.4 |
| **Respiratory Rate (breaths/min)** | 51.3 ± 10.3 | 51.0 ± 11.3 | 51.2 ± 10.5 |
| **Tidal Volume (l)** | 1.25 ± 0.60 | 1.32 ± 0.50 | 1.28 ± 0.51 |
| **Minute Ventilation: $\dot{V}E$ (l.min$^{-1}$)** | 60.9 ± 19.0 | 63.4 ± 14.0 | 62.1 ± 17.0 |
| **Maximal voluntary ventilation (l)** | 81.9 ± 25.4 | 82.4 ± 22.6 | 82.1 ± 24.0 |
| **Dyspnoeic Index ($\dot{V}E$/MVV)** | 0.74 ± 0.24 | 0.77 ± 0.12 | 0.76 ± 0.20 |
| **Breathing Reserve %** | 26.0 ± 8.6 | 23.0 ± 12.4 | 25.0 ± 10.5 |
| **Oxygen equivalent (l)** | 32.6 ± 5.7 | 36.1 ± 4.4 | 34.1 ± 5.4 |
| **Carbon dioxide equivalent (l)** | 29.8 ± 4.7 | 31.3 ± 4.2 | 30.5 ± 4.5 |
| **GXT time (mins)** | 8.50 ± 1.3 | 8.54 ± 0.73 | 8.52 ± 1.10 |
| **End tidal oxygen pressure (kPa)** | 15.4 ± 0.94 | 15.8 ± 0.53 | 15.6 ± 0.82 |
| **End tidal carbon dioxide pressure (kPa)** | 4.77 ± 0.80 | 4.54 ± 0.54 | 4.70 ± 0.70 |

Mean ± SD

$^{\dagger}$ significantly different from females ($p<0.04$)

### 5.3.4.1 Comparative analysis – school-tested and laboratory-tested peak $\dot{V}O_2$ and peak heart rate

Peak $\dot{V}O_2$ (from GXT or predicted from 6MRD) and peak heart rate data for ‘school-tested’ non-asthmatics, ‘school-tested’ asthmatics and ‘laboratory-tested’ asthmatics are shown in Table 5.4 (males) and Table 5.5 (females). No significant differences were shown in peak $\dot{V}O_2$ or peak heart rate between any of the three groups within each gender ($p>0.05$).

**Table 5.4 Comparison of male peak $\dot{V}O_2$ data**

| | **School Tested Non-asthmatic Males (Estimated peak $\dot{V}O_2$)** (n = 314) | **School Tested Asthmatic Males (Estimated peak $\dot{V}O_2$)** (n = 74) | **Laboratory Tested Asthmatic Males (Peak $\dot{V}O_2$ via indirect calorimetry)** (n = 19) |
|---|---|---|---|
| **Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 47.2 ± 5.9 | 46.6 ± 5.9 | 45.3 ± 9.3 |
| **Peak heart rate (bpm)** | 196.1 ± 9.3 | 194.5 ± 10.6 | 192.0 ± 6.3 |

Mean ± SD

**Table 5.5 Comparison of female peak $\dot{V}O_2$ data**

| | School Tested Non-asthmatic Females (Estimated peak $\dot{V}O_2$) (n = 321) | School Tested Asthmatic Females (Estimated peak $\dot{V}O_2$) (n = 51) | Laboratory Tested Asthmatic Males (Peak $\dot{V}O_2$ via indirect calorimetry) (n = 13) |
|---|---|---|---|
| **Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 43.2 ± 5.2 | 42.5 ± 5.0 | 41.3 ± 5.9 |
| **Peak heart rate (bpm)** | 194.1 ± 10.7 | 189.5 ± 13.6 | 191.0 ± 7.7 |

Mean ± SD

### 5.3.4.2 Comparative analysis - GXT responses between severe asthmatics and non-asthmatic

Table 5.6 displays GXT data from the 'laboratory-tested' severe asthmatics and GXT data from 'laboratory-tested' non-asthmatics. The non-asthmatic data were gathered using a modified Bruce treadmill protocol, in which speed and elevation were increased every three minutes. Either a Cosmed $K4b^2$ or K4RQ metabolic analysis system was employed for indirect calorimetry measurements. Data were gathered for two separate studies (Toohey, 2000; Bate, 2001) that acted as pilot work for the current study.

Non-asthmatic males were 12.4% older ($t[47]=2.26$; $p=0.02$), had a 28% greater tidal volume ($t[47]=2.49$; $p=0.01$), a 42.3% greater $\dot{V}E$ ($t[47]=4.70$; $p<0.0001$), and a 4% greater peak heart rate ($t[47]=2.31$; $p=0.02$) when compared to severe asthmatic males. Non-asthmatic females had a 15% greater respiratory rate ($t[56]=2.33$; $p=0.02$) compared to severe asthmatic females. There were no significant differences in peak $\dot{V}O_2$ between severe asthmatics and non-asthmatics for either gender ($p>0.05$).

**Table 5.6 Comparison of GXT responses between laboratory-tested severe asthmatics and non-asthmatics**

| | Non-Asthmatic Males (n=30) | Severe Asthmatic Males (n=19) | Non-Asthmatic Females (n=45) | Severe Asthmatic Females (n=13) |
|---|---|---|---|---|
| **Age (years)** | 12.5 ± 1.6[†] | 11.12 ± 2.56 | 12.70 ± 1.60 | 12.01 ± 2.10 |
| **Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 49.5 ± 8.0 | 45.3 ± 9.3 | 43.3 ± 8.3 | 41.3 ± 5.9 |
| **Respiratory exchange ratio** | 1.10 ± 0.10 | 1.10 ± 0.10 | 1.13 ± 0.11 | 1.15 ± 0.10 |
| **$\dot{V}E$ ($l.min^{-1}$)** | 86.7 ± 18.6* | 60.9 ± 19.0 | 67.4 ± 16.8 | 63.4 ± 14.0 |
| **Tidal volume (l)** | 1.60 ± 0.42[†] | 1.25 ± 0.60 | 1.18 ± 0.35 | 1.32 ± 0.50 |
| **Respiratory rate (breaths/min)** | 55.7 ± 9.5 | 51.3 ± 10.3 | 58.6 ± 10.0[†] | 51.0 ± 11.3 |
| **Peak heart rate (bpm)** | 198.9 ± 9.7[†] | 192.0 ± 6.3 | 198.8 ± 7.1 | 191.0 ± 7.7 |

Mean ± SD

[†] significantly different from 'laboratory-tested' severe asthmatics of the same gender ($p<0.03$)

*significantly different from 'laboratory-tested' severe asthmatics of the same gender ($p<0.0001$)

### 5.3.5 Physical Activity Data

Mean PAQ-C, activity monitor counts and estimated MET values are shown in Table 5.7. Males had a 51% greater (t[30]=4.41; p=0.0001) mean PAQ-C value in comparison to females (see Figure 5.4). However, no differences were reported between males and females in terms of activity monitor counts or estimated MET values. In accordance with age-specific thresholds (Trost, 2001), the amount of time and the proportion of time spent in each intensity range per day is shown in Table 5.8 (Appendix N: Chapter 6 Appendices). No differences between males and females were observed for the amount of time spent in each intensity range nor the proportion of time in each intensity range.

**Table 5.7 Physical activity of 10-16 year old severely asthmatic participants**

| | **Males** | **Females** | **All** |
|---|---|---|---|
| **PAQ-C** | $3.16 \pm 0.60^{\dagger}$ (n = 19) | $2.05 \pm 0.84$ (n = 13) | $2.70 \pm 0.90$ (n = 32) |
| **Activity monitor counts (counts/min)** | $302.9 \pm 150.6$ (n = 9) | $269.0 \pm 60.6$ (n = 7) | $288.1 \pm 143.6$ (n = 16) |
| **Estimated MET ($ml.kg^{-1}.min^{-1}$)** | $2.07 \pm 0.50$ (n = 9) | $1.95 \pm 0.30$ (n = 7) | $2.01 \pm 0.40$ (n = 16) |

Mean ± SD

† significantly different from females (p<0.0001)

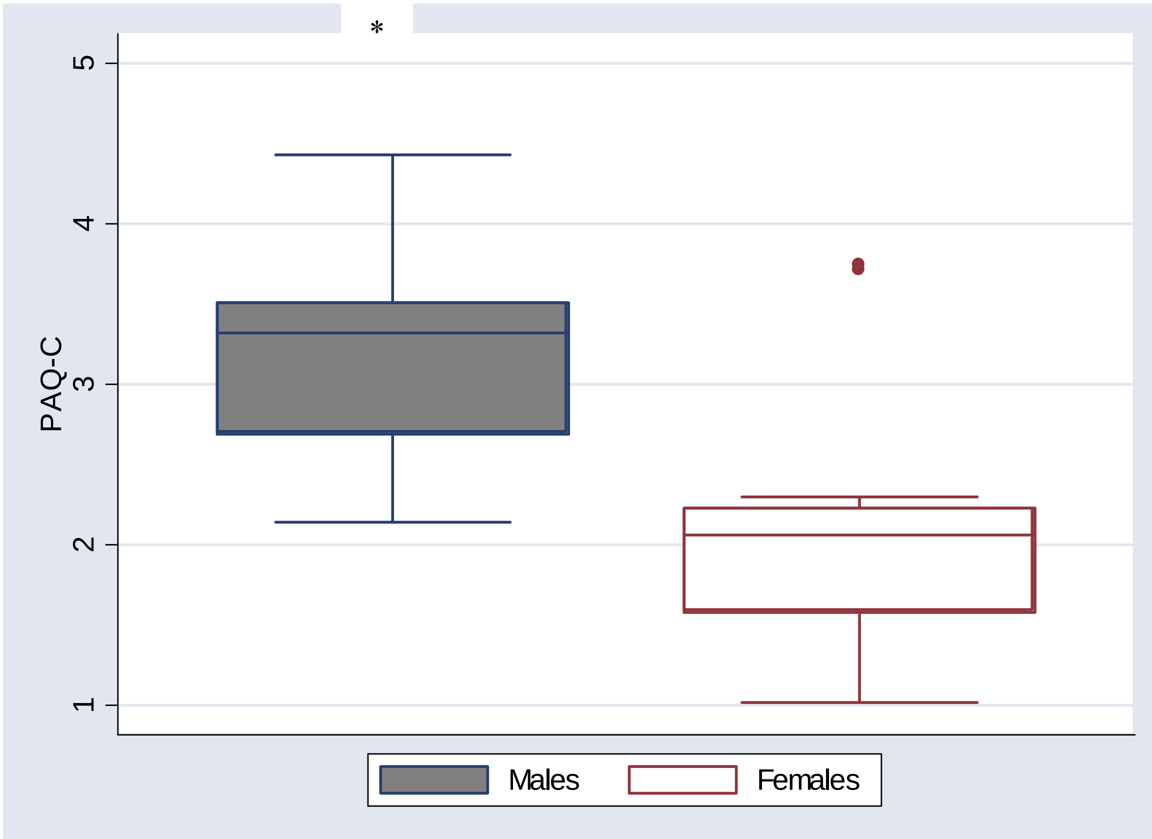



**Figure 5.4 Comparison of PAQ-C values between 19 laboratory-tested severely asthmatic males and 13 severely asthmatic laboratory-tested females aged 10-16 years.** Box-whisker plots show the mean and 95% confidence intervals. Outliers represent those values outside the 95% confidence interval.

PAQ-C = Physical Activity Questionnaire for Children.

* significantly different from laboratory-tested severely asthmatic females (p<0.001).

### 5.3.6 Relationship between Activity Monitor Counts and PAQ-C Data

Correlation analysis results for the relationship between activity monitor counts and PAQ-C data are shown in Table 5.9 (Appendix N: Chapter 6 Appendices). No associations between activity monitor counts and PAQ-C data were observed for either males or females or the combined data set.

#### 5.3.6.1 Comparative analysis - school-tested versus laboratory-tested physical activity

PAQ-C, activity monitor counts and estimated MET data for ‘school-tested’ non-asthmatics, ‘school-tested’ asthmatics and ‘laboratory-tested’ severe asthmatics are shown in Table 5.10 (males) and Table 5.11 (females). School-tested non-asthmatic females had a 34% greater (t[332]=3.55; p=0.0004) PAQ-C value when compared to laboratory-tested females.

**Table 5.10 Comparison of male physical activity data**

| | School Tested Non-Asthmatic Males | School Tested Asthmatic Males | Laboratory Tested Asthmatic Males |
|---|---|---|---|
| **PAQ-C** | 3.21 ± 0.70 (n = 314) | 3.20 ± 0.64 (n = 74) | 3.16 ± 0.60 (n = 19) |
| **Activity monitor counts (counts/min)** | 512.9 ± 257.0 (n = 12) | 411.4 ± 177.4 (n = 12) | 302.9 ± 150.6 (n = 9) |
| **Estimated MET ($ml.kg^{-1}.min^{-1}$)** | 2.20 ± 0.40 (n = 12) | 2.10 ± 0.25 (n = 12) | 2.07 ± 0.50 (n = 9) |

Mean ± SD

**Table 5.11 Comparison of female physical activity data**

| | School Tested Non-Asthmatic Females | School Tested Asthmatic Females | Laboratory Tested Asthmatic Females |
|---|---|---|---|
| **PAQ-C** | 2.74 ± 0.70† (n = 321) | 2.51 ± 0.60 (n = 51) | 2.05 ± 0.84 (n = 13) |
| **Activity monitor counts (counts/min)** | 320.7 ± 112.0 (n = 14) | 351.1 ± 213.0 (n =17) | 269.0 ± 60.6 (n = 7) |
| **Estimated MET ($ml.kg^{-1}.min^{-1}$)** | 2.00 ± 0.21 (n = 14) | 2.02 ± 0.25 (n = 17) | 1.95 ± 0.30 (n = 7) |

Mean ± SD

† significantly different from laboratory-tested asthmatics ($p < 0.01$)

### 5.3.7 Relationship between Peak $\dot{V}O_2$ and BMI

Mean peak $\dot{V}O_2$ values for the laboratory-tested severe asthmatics, grouped by gender and categorised according to the BMI cutoff points of Cole *et al.* (2000), are shown in Table 5.12. For the purpose of analysis, overweight and obese groups were combined. Regression analysis results for the relationship between peak $\dot{V}O_2$ and BMI are shown in Table 5.13 and the data illustrated in Figure 5.5. Males in the normal BMI category had a 27.7% greater ($t[17]=2.43$; $p=0.02$) peak $\dot{V}O_2$ value in comparison to their overweight/obese peers. According to regression analyses, both males and females demonstrated positive associations between $\dot{V}O_2$ and BMI. For male and female combined data, regression analyses revealed that BMI accounted for 27% of the variance in $\dot{V}O_2$ (Figure 5.5).

**Table 5.12 Peak $\dot{V}O_2$ stratified according to the BMI categories of Cole *et al.* (2000)**

| Group | Variable | Normal BMI | Overweight/Obese BMI |
|---|---|---|---|
| **Males** | **Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 48.04 ± 7.20† (n=14) | 37.60 ± 10.90 (n=5) |
| **Females** | **Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 42.50 ± 6.70 (n=7) | 39.30 ± 2.00 (n=6) |

Mean ± SD

† significantly different from the overweight/obese BMI groups ($p<0.03$)

**Table 5.13 Regression analysis for $\dot{V}O_2$ and BMI**

| Group | Regression Equation | $R^2$ | p |
|---|---|---|---|
| **Males** | $\dot{V}O_2 =$ 101.3 (BMI) -116.1 | 0.37 | 0.002 |
| **Females** | $\dot{V}O_2 =$ 55.5 (BMI) + 571.0 | 0.11 | 0.027 |

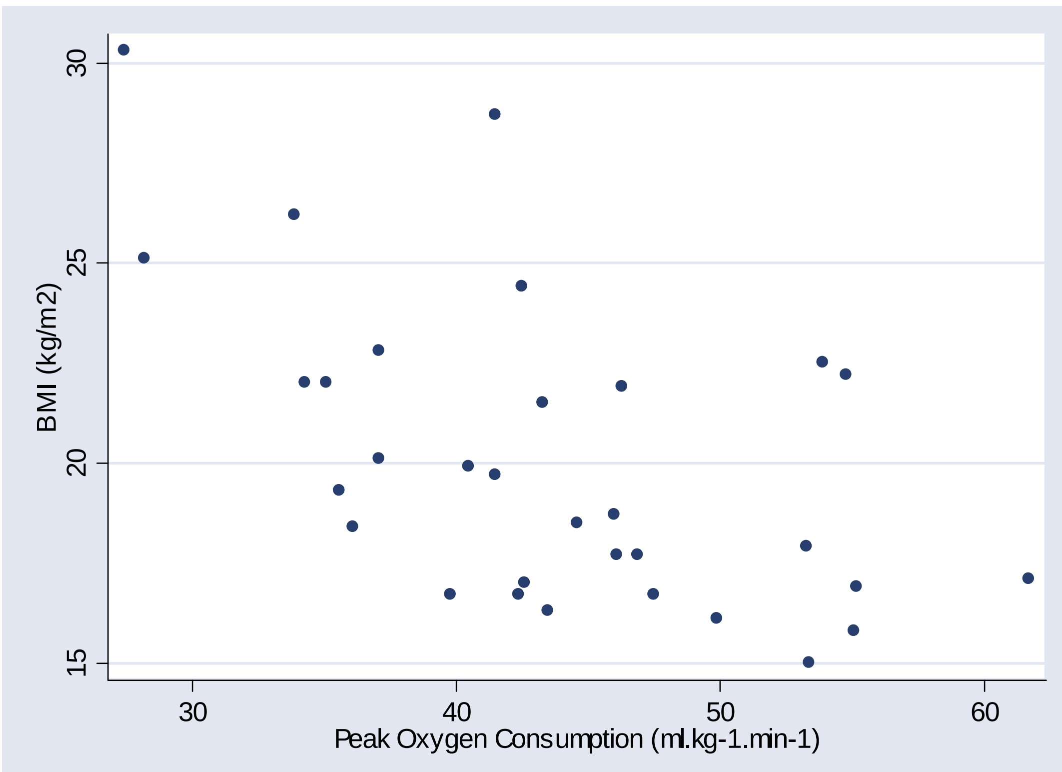



**Figure 5.5 Scatterplot of BMI versus peak $\dot{V}O_2$ in 32 severely asthmatic laboratory tested children and adolescents aged 10 to 16 years.** Scatterplot demonstrates a significant inverse association between BMI and peak $\dot{V}O_2$. BMI= Body mass index ($kg/m^2$).

### 5.3.8 Relationship between Peak $\dot{V}O_2$ and Physical Activity

Regression analysis results for the relationship between peak $\dot{V}O_2$ and physical activity (PAQ-C, activity monitor counts, estimated MET) are shown in Table 5.14 (Appendix N: Chapter 6 Appendices) and graphically represented in Figure 5.6. Males and females both demonstrated positive associations between peak $\dot{V}O_2$ and all measures of physical activity, however, no significant associations were identified. The regression between peak $\dot{V}O_2$ and PAQ-C for the male and female combined data set (n=32) was the only result to reach significance ($R^2 = 0.19$; p=0.01).

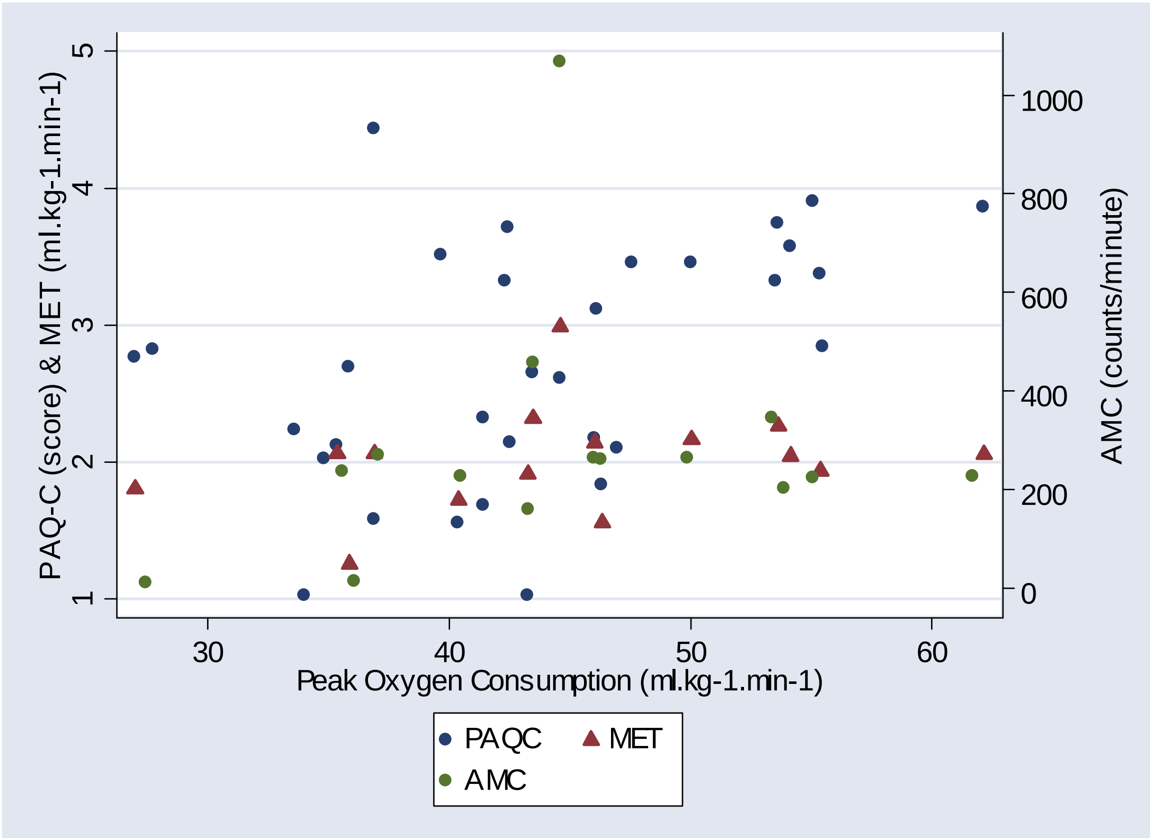



**Figure 5.6 Scatterplots of measures of physical activity versus peak $\dot{V}O_2$ in laboratory-tested severely asthmatic participants aged 10 to 16 years.** Thirty-two data points are shown for PAQ-C and 16 data points shown for activity monitor counts and estimated MET. Scatterplots demonstrate a significant positive association between peak $\dot{V}O_2$ and PAQ-C, and a lack of association between peak $\dot{V}O_2$ and activity monitor counts and peak $\dot{V}O_2$ and estimated MET. AMC = Activity monitor counts; MET = metabolic equivalent; PAQ-C = Physical Activity Questionnaire for Children.

Regression analysis equations:

Peak $\dot{V}O_2$ = 4.10 (PAQ-C) + 32.51 ($R^2$=0.19; p=0.01)

Peak $\dot{V}O_2$ = 0.01 (Activity Monitor Counts) + 43.02 ($R^2$=0.03; p=0.50)

Peak $\dot{V}O_2$ = 6.15 (Esimated MET) + 32.50 ($R^2$=0.07; p=0.34)

### 5.3.9 Relationship between Physical Activity and BMI

Mean PAQ-C, activity monitor counts and estimated MET values grouped by gender and categorised according to the BMI cutoff points of Cole *et al.* (2000) are shown in Table 5.15. For the purpose of analysis, overweight and obese groups were combined. Within the limitations of small group sizes, males and females demonstrated no significant differences between BMI strata for any measure of physical activity. Furthermore, despite regression analyses showing males and females having inverse associations between all measures of physical activity and BMI, no relationship achieved significance (see Table 5.16, Appendix N: Chapter 6 Appendices). The relationships between physical activity and BMI are illustrated in Figure 5.7.

**Table 5.15 Physical activity stratified according to the BMI categories of Cole *et al.* (2000)**

| Group | Variable | Normal BMI | Overweight/Obese BMI |
|---|---|---|---|
| **Males** | **PAQ-C** | 3.16 ± 0.51 (n=14) | 3.18 ± 0.40 (n=5) |
| | **Activity Monitor Counts** | 374.4 ± 149.9 (n=6) | 160.0 ± 84.5 (n=3) |
| | **Estimated MET** | 2.12 ± 0.60 (n=6) | 2.00 ± 0.81 (n=3) |
| **Females** | **PAQ-C** | 2.05 ± 0.80 (n=7) | 2.13 ± 1.00 (n=6) |
| | **Activity Monitor Counts** | 287.4 ± 27.5 (n=6) | 158.7 (n=1) |
| | **Estimated MET** | 1.95 ± 0.30 (n=6) | 1.91 (n=1) |

Mean ± SD

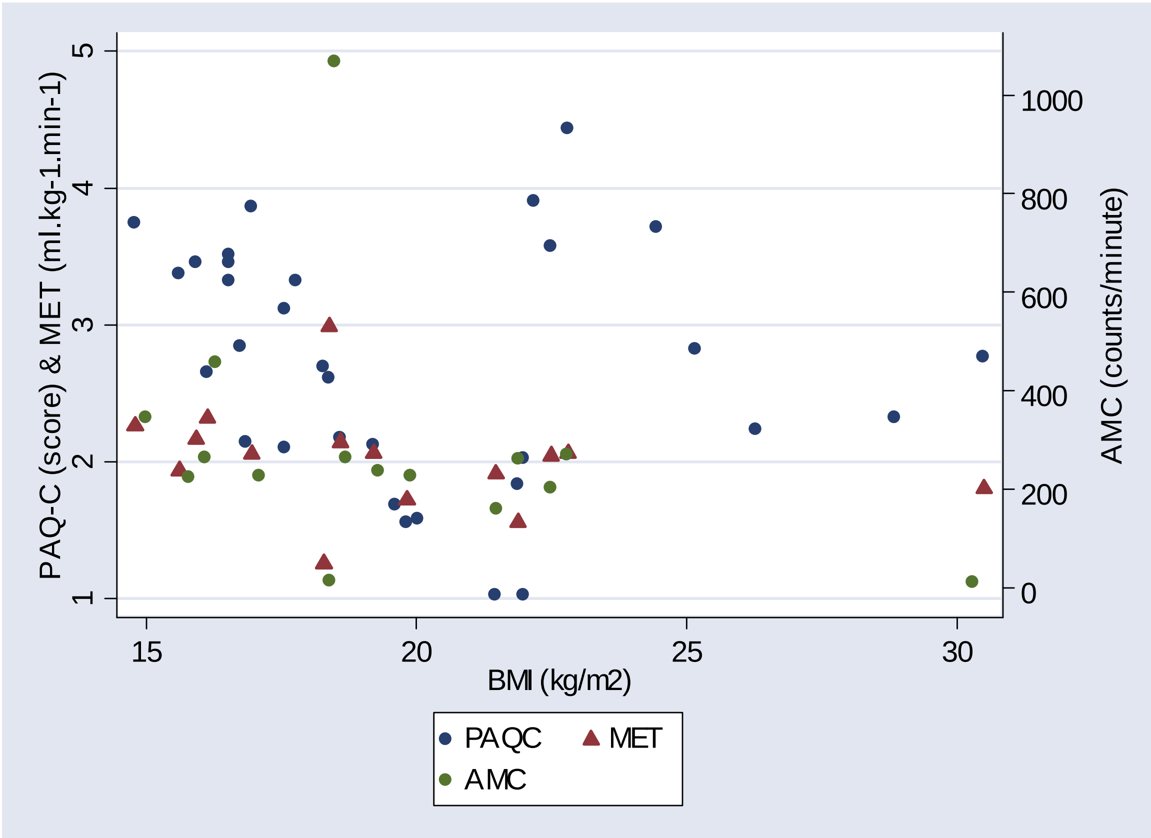



**Figure 5.7 Scatterplots of measures of physical activity and body mass index in laboratory-tested severely asthmatic children and adolescents aged 10 to 16 years.**

Scatterplots demonstrate a lack of association between BMI and measures of physical activity. Thirty-two data points are shown for PAQ-C and 16 data points shown for AMC and estimated MET. AMC = activity monitor counts; PAQ-C = Physical Activity Questionnaire for children; MET = metabolic equivalent.

Regression analysis equations:

BMI = -0.80 (PAQ-C) + 22.22 ($R^2$=0.03; p=0.33)

BMI = -0.01 (Activity Monitor Counts) + 21.10 ($R^2$=0.11; p=0.19)

BMI = -2.94 (Estimated MET) + 25.54 ($R^2$=0.08; p=0.29)

### 5.3.10 Odds Ratios and the Relationship between Asthma Status and Body Composition

Table 5.17 shows the odds ratios for ‘laboratory-tested’ severe asthmatic participants (grouped according to gender) being overweight or obese in comparison to ‘school-tested’ asthmatic and non-asthmatic participants (also grouped according to gender). For example, Table 5.17 shows that laboratory-tested severely asthmatic females are 2.1 times more likely to be overweight, and 3.19 times more likely to be obese in comparison to ‘school-tested’ non-asthmatic females. Mantel-Haenszel odds ratios for male and female combined data are shown in Table 5.18, showing that laboratory-tested severe asthmatics are 3.17 times more likely to obese in comparison to school-tested non-asthmatics and 1.6 times more likely to be obese in comparison to school-tested asthmatics. Although a limited number of odds ratios suggest severe asthma to be protective against overweight/obesity, this may be the result of the poor power of the sample size of the laboratory-tested participants.

**Table 5.17 Odds ratios for laboratory-tested severe asthmatic participants being overweight or obese in comparison to school-tested asthmatic and non-asthmatic participants**

| Group | Odds ratio for overweight BMI | Odds ratio for obesity BMI |
|---|---|---|
| **School Tested Non-Asthmatic Males** | 0.90 (0.25-3.25) | 3.17 (0.63-15.85) |
| **School Tested Non-Asthmatic Females** | 2.10 (0.62-7.05) | 3.19 (0.36-28.14) |
| **School-Tested Asthmatic Males** | 0.60 (0.15-2.34) | 1.20 (0.21-6.64) |
| **School-Tested Asthmatic Females** | 1.14 (0.30-4.37) | 4.00 (0.21-34.14) |

Odds Ratios (95% CI)

**Table 5.18 Mantel-Haenszel odds ratios for laboratory-tested severe asthmatic participants being overweight or obese in comparison to asthmatic and non-asthmatic participants controlled for gender**

| Group | Odds ratio for overweight | Odds ratio for obesity |
|---|---|---|
| **School Tested Non-Asthmatics** | 1.35 (0.56-3.20) | 3.17 (0.87-11.60) |
| **School Tested Asthmatics** | 0.82 (0.32-2.10) | 1.60 (0.37-6.68) |

Odds Ratios (95% CI)

## 5.3.11 Multiple Regression Analyses

Multiple regression analyses for the relationships between peak $\dot{V}O_2$ (dependent variable) and BMI, measures of physical activity and FER are shown in Table 5.19. Each regression model, independent of the physical activity assessment technique employed, reached significance. The regression model still achieved significance with the physical activity measures removed. However, the model failed to demonstrate significance when BMI was withdrawn, regardless of the physical activity method used (see Table 5.20, Appendix N: Chapter 6 Appendices).

**Table 5.19 Multiple regression analyses - peak $\dot{V}O_2$, physical activity, BMI and forced expiratory ratio**

| Physical Activity Method | Regression Equation | $R^2$ | p |
|---|---|---|---|
| **PAQ-C** | Peak $\dot{V}O_2$ = -1.44 (BMI) + 3.06 (PAQ-C) + 0.10 (FER) + 48.8 | 0.44 | 0.001 |
| **Activity monitor couonts** | Peak $\dot{V}O_2$ = -1.74 (BMI) + 0.0002 (Activity Monitor Counts) + 0.56 (FER) + 28.4 | 0.59 | 0.01 |
| **Estimated MET** | Peak $\dot{V}O_2$ = -1.73 (BMI) + 0.29 (MET) + 0.55 (FER) + 28.1 | 0.59 | 0.01 |
| **Physical activity not included in the model** | Peak $\dot{V}O_2$ = -1.32 (BMI) + 0.20 (FER) | 0.35 | 0.001 |

## 5.4 Discussion

Despite efforts for consensus regarding the assessment of asthma severity (National Asthma Education and Prevention Program, 1997), no ‘gold standard’ protocol/definition is recognised for its evaluation. Consequently, clinicians and research staff alike employ an array of methods, both subjective and objective, to classify disease severity. Classical asthma symptoms including wheeze (Rosier *et al.*, 1994), pulmonary function (National Asthma Education and Prevention Program, 1997), medication habits (Lang *et al.*, 2004), and/or hospitalisations and school absenteeism (Szentagothai *et al.*, 1987) have all been used. As a result, comparability between studies is often difficult.

However severity is defined, it is overtly clear that there is a shortage of literature in relation to the aerobic fitness and physical activity levels of severely asthmatic children and adolescents. Few studies have examined aerobic fitness (Bevegård *et al.*, 1971; Strunk *et al.*, 1988; Fink *et al.*, 1992; Pianosi & Davis, 2004) and physical activity (Lang *et al.*, 2004; Pianosi & Davis, 2004) in severe asthmatics, with outcomes between these studies lacking agreement. Evidently, a need exists to elucidate whether severe asthmatics display deficits in fitness and activity levels.

In addition, few studies have investigated the association between excess body mass and asthma severity in children (Luder *et al.*, 1998; Belamarich *et al.*, 2000; von Mutius *et al.*, 2001; Tantisira *et al.*, 2003). Although the majority of studies demonstrated increases in asthma symptoms with increases in body mass (Luder *et al.*, 1998; Belamarich *et al.*, 2000; von Mutius *et al.*, 2001), some studies counter this view (Gennuso *et al.*, 1998; Tantisira *et* *al.*, 2003). Moreover, a paucity of literature addresses the influence of excess body mass on aerobic fitness and physical activity levels in severely asthmatic children and adolescents.

The BMI results of this study provide evidence to support the suggested association between increased asthma incidence and excess body mass. According to the gender- and age-specific cutoff points of Cole *et al.* (2000), 34.3% of the severe asthmatics were classified as overweight or obese. This prevalence rate is in agreement with the pattern described in the asthmatic youth in Chapter 4 (30.4%), which is more pronounced than the 21.1% reported for non-asthmatics in Chapter 3. The severely asthmatic cohort was more likely to be overweight and obese than their non-asthmatic and less severely affected asthmatic peers, supported in general, by odds ratio analyses (see Tables 5.17 and 5.18). These outcomes are consistent with previous findings showing links between asthma severity and excess body mass (Luder *et al.*, 1998; Belamarich *et al.*, 2000; von Mutius *et al.*, 2001). A limited number of odds ratios did suggest severe asthma to be protective against overweight/obesity, however, this is more likely the result of the poor power of the sample size of the laboratory-tested participants.

As discussed in Chapter 4, several specific mechanisms are thought to contribute to the augmented prevalence of overweight and obesity among asthmatics. These include the proposal of a smooth muscle 'latching' state which is believed to result in reduced airway calibre and increased bronchial hyper-responsiveness (Fredberg *et al.*, 1996; Fredberg *et al.*, 1997; Fredberg, 2000). In addition, some overlap in genes may be important in the association between asthma and obesity (Shore & Johnston, 2006). Genome-wide scans for asthma have indicated consensus linkage regions on chromosomes 5q, 6p, 11q, and 12q (Weiss & Raby, 2004), and these regions contain some candidate genes for obesity (Tantisira & Weiss, 2001; Weiss & Caprio, 2005). For example, the region on 5q contains the $\beta_2$-adrenergic receptor ($\beta_2$-AR) and $\beta_2$-agonists are the key form of rescue medication in asthma (Turki *et al.*, 1995; Israel *et al.*, 2001). Moreover, it has also been suggested that common *in utero* conditions may play a role in the development of both asthma and obesity. Alterations in the intrauterine nutritive environment can result in diminished fetal growth during early gestation or increased birth weight during late gestation; both of which are associated with obesity. Fetal programming and the extremes of birth weights are also thought to lead to asthma (Barker, 1991; Law *et al.*, 1992; Hediger *et al.*, 1998; Gold *et al.*, 2003; Shore *et al.*, 2003).

A major finding from the present work is that severely asthmatic children and adolescents displayed comparable levels of aerobic fitness to those produced by the less severely affected 'school-tested' asthmatics and 'school-tested' non-asthmatics of a similar age (see Tables 5.4 and 5.5). Moreover, severely asthmatic children also demonstrated similar aerobic fitness levels to untrained non-asthmatics of comparable age (see Tables 5.6 and 5.21). This demonstrates that even the children/adolescents most affected by asthma maintained the ability to achieve levels of exercise performance comparable to non-sufferers. Potentially high levels of fitness in children with all categories of asthma also indicate that severely asthmatic youths are likely able to tolerate levels of exercise training which can improve cardio-respiratory fitness. This finding may help to bridge the knowledge gap about whether an added ventilatory limitation to exercise is present in asthmatic youth.

**Table 5.21 Comparison of GXT responses between laboratory-tested severe asthmatics (current study) and the non-asthmatic literature**

| | **Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | **Peak heart rate (bpm)** | **$\dot{V}E$ ($l.min^{-1}$)** | **Oxygen pulse ($ml.kg^{-1}.beat^{-1}$)** | **Respiratory exchange ratio** |
|---|---|---|---|---|---|
| **(LT) Severe Asthmatics** (n = 32, 11.50 ± 0.41 y) | 43.7 ± 8.2 | 191.6 ± 6.8 | 62.1 ± 17.0 | 0.22 ± 0.05 | 1.12 ± 0.10 |
| **Fink *et al*., 1993** (n = 16, 11.4 ± 1.5 y) | 43.0 ± 7.0 | NR | 65.6 ± 24.0 | NR | NR |
| **Armstrong *et al*., 1995** (n = 46, 11.0 ± 0.4 y) | 45.5 ± 5.0 | 200.0 ± 7.0 | NR | NR | 1.05 ± 0.08 |
| **Armstrong *et al*., 1999** (n = 174, 13.1± 0.04 y) | 47.5 ± 7.8 | 201.0 ± 7.0 | NR | 0.24 ± 0.04 | 1.04 ± 0.06 |
| **Douard *et al*., 1997** (n = 43, 12.8 ± 3.4 y) | 44.7 ± 6.1 | NR | 69.3 ± 30.1 | 0.24 ± 0.10 | 1.14 ± 0.12 |

Mean ± SD, NR = not reported, LT = laboratory-tested

Given this information, it is reasonable to suggest that severely asthmatic children and adolescents who require large doses of daily steroid treatment may be able to realise many of the health benefits associated with a physical conditioning program (Baquet *et al.*, 2003), and as such, may tolerate a reduction in medication usage. Despite several paediatric studies reporting reductions in asthma medication following cardio-respiratory training (Huang *et al.*, 1989; Engstrom *et al.*, 1991; Wardell & Isbister, 2000), conflicting information exists on the effects that training has on exercise-induced asthma (Welsh *et al.*, 2005), and as such, medication habits need to be individualised.

In terms of exercise-induced asthma, a recent review by Welsh *et al.* (2005) focusing on the effects of physical conditioning in children and adolescents with asthma identified four studies in which a benefit in exercise-induced asthma from training was demonstrated and nine reports showing no alteration. Consequently, the effect that training has on exercise-induced asthma is controversial. However, the four studies showing reductions in exercise-induced asthma (Henriksen *et al.*, 1981; Henriksen & Nielsen, 1983; Svenonius *et al.*, 1983; Matsumoto *et al.*, 1999) used similar workloads for their exercise challenges before and after training but did not establish a control for $\dot{V}_E$. Trained subjects with an improved aerobic fitness level will employ a lower $\dot{V}_E$ for a given workload compared to their pre-training level and, as a result, a less intense exercise-induced asthma stimulus will be encountered compared with the pre-training situation (Orenstein, 2002). Therefore, the findings of the four aforementioned studies may be a result of an altered $\dot{V}_E$ rather than a modification of the underlying bronchial hyper-responsiveness. Interestingly, only two studies have investigated the effects of training on the pathophysiology of asthma in children and both report that histamine sensitivity showed no reduction post-training (Matsumoto *et al.*, 1999; Wardell & Isbister, 2000). Despite these findings, if aerobic conditioning can reduce the probability of eliciting an exercise-induced asthma response due to decreased ventilatory requirements at a given workload, then all asthmatic children, including those severely affected, should aim to achieve the greatest level of aerobic fitness possible.

The GXT data generated by this group indicate their maximal voluntary ventilation was unhindered by their disease and that bronchial hyper-responsiveness did not impose any significant limitation on exercise performance (see Table 5.3). The dyspnoeic index ($\dot{V}_E$/MVV) remained below 0.80 and, therfore, breathing reserve at peak exercise was still considerable at a mean 25.0%. Moreover, results for oxygen pulse responses in severe asthmatic participants compare favourably with the non-asthmatic literature (see Table 5.21) which suggests an equivalent cardiovascular efficiency. Previous reports of asthmatics recording a significantly greater absolute $\dot{V}_E$ for a given workload than non-asthmatics signifies ventilatory inefficiency (Cropp & Tanakawa, 1977; Robinson *et al.*, 1992). However, the asthmatic adolescents in this study displayed comparable levels of $\dot{V}_E$ to the age-matched non-asthmatic participants (see Table 5.21). This similarity may be due to the 500 μg of daily steroid therapy.

It is possible that 'laboratory-tested' asthmatics may achieve similar levels of $\dot{V}_E$ to non-asthmatics by employing an irregular breathing pattern. When matched against an age-matched 'laboratory-tested' non-asthmatic group, the severe asthmatic females in this study demonstrated a significantly lower breathing frequency and a greater mean tidal volume (see

Table 5.6). Although the mechanisms responsible for this breathing pattern are not completely understood, several groups support the concept that an altered breathing pattern may improve the ventilatory function of exercising asthmatic subjects (Cropp & Tanakawa, 1977; Ramonatxo *et al.*, 1989; Ceugniet *et al.*, 1996; Santuz *et al.*, 1997). Specifically, exercise-induced asthma (whether its cause is instigated by respiratory heat loss or increased osmolarity due to water loss) seems to be related to $\dot{V}_E$ and breathing pattern (Solway *et al.*, 1985; Ingenito *et al.*, 1986; Clark, 1992). A slow and deep pattern of breathing will produce a more laminar respiratory airflow, which reduces the heat and water exchange within the tracheobronchial tree and, therefore, exercise-induced asthma (McFadden, 1990). This breathing pattern also decreases the proportion of dead space ventilation to total ventilation, allowing lower ventilation overall and, hence, a reduced stimulus for exercise-induced asthma (Paul *et al.*, 1966). These arguments support the concept that asthmatics should benefit from adopting a slow and deep breathing pattern during exercise. Conversely, it has also been suggested that asthmatics should not be encouraged to modify their breathing pattern because the pattern spontaneously employed by each individual may be best-suited to their pathophysiological status in order to optimally minimise dyspnoea during exercise (Ceugniet *et al.*, 1996). This phenomena was not present when comparing male groups, but, the 'laboratory-tested' male non-asthmatics were significantly older which may account for disparity between male and female breathing patterns. Again however, it should be noted that adjustments for maturation would have allowed a more thorough statistical analysis of the data, and it is acknowledged as a limitation of the study.

A number of possible explanations may underlie the aerobic fitness levels observed in the severe asthmatic group. Although FER was reduced among severe asthmatics in comparison to the ‘school- tested’ participants (see Figure 5.3), severe asthmatics had mean $FEV_1$ % predicted results within the normal healthy range (Zapletal *et al.*, 1987) and generally showed only very mild signs of airway obstruction. Moreover, participants were pre-medicated with a bronchodilator prior to exercise. Additionally, one could speculate that severe asthmatic participants were more motivated (i.e. more physically active, had better medication adherence and, therefore, better controlled asthma) than those who did not elect to become involved. Indeed, one training study of ten severely asthmatic children found that only psychological modifications correlated significantly with aerobic improvement (Engstrom *et al.*, 1991). Hence, individual variations in acceptance and knowledge of the disease may influence physical activity, fitness and adherence to medication usage. Perhaps only among severe asthmatics in whom a high degree of fixed airway obstruction or bronchial hyper-responsiveness is present (i.e. uncontrolled severe asthmatics) would a deficit in aerobic fitness be revealed. Such conditions would likely lead to a reduction in maximal voluntary ventilation (Fairshter *et al.*, 1989; Anderson, 1993) and, consequently, these individuals may not have the ventilatory reserve required, or indeed the tolerance, to train at exercise intensities sufficient to produce improvements in cardio-respiratory fitness.

Methodological differences in previous work relating to the exercise performance of severely asthmatic children have most likely contributed to the equivocal nature of the available data. For example, some groups have administered a bronchodilator prior to exercise (Strunk *et al.*, 1988; Pianosi & Davis, 2004) while others have not (Bevegård *et al.*, 1971; Fink *et al.*, 1992). Sample sizes are typically small and not all studies have included a non-asthmatic control group (Strunk *et al.*, 1988; Pianosi & Davis, 2004). Moreover, the methods used for the assessment of asthma severity and fitness vary. Strunk *et al.* (1988) employed a 9-minute run for severe asthmatics and so did not measure ventilation or gas exchange. However, it is severe asthmatic patients in whom the measurement of such parameters is most important. In addition, Pianosi *et al.* (2004) and Bevegård *et al.* (1971) both used a cycle ergometer to assess fitness. Pianosi *et al.* (2004) admitted that most children discontinued the exercise test due to muscular fatigue in their legs rather than reaching a ventilatory endpoint. In physical conditioning studies of severely asthmatic youth, some have failed to include a non-asthmatic control group (Nickerson *et al.*, 1983; Ludwick *et al.*, 1986; Engstrom *et al.*, 1991), so the ability to make conclusions is limited.

The ‘laboratory-tested’ severe asthmatics in this study also displayed an inverse association between aerobic fitness and BMI, as observed in the participants of Chapters 3 and 4. Again, however, physical activity failed to account for this relationship because no associations between measures of physical activity and BMI were observed, and a weak yet significant association between PAQ-C and aerobic fitness ($R^2$=0.19) was detected (see Tables 5.14 & 5.16). Although multiple regression analyses for the prediction of peak $\dot{V}O_2$ remained significant with the inclusion of a physical activity covariate, the removal of BMI from the model resulted in a loss of significance (see Tables 5.19 & 5.20).

The fact that physical activity could only partially explain the inverse association between aerobic fitness and BMI suggests that other factors are responsible. As discussed in Chapter

4, obesity can cause dyspnoea unrelated to airflow obstruction, including increased work of breathing and deconditioning (Martinez *et al.*, 1994; Schachter *et al.*, 2001; Sin *et al.*, 2002). Therefore, some overweight and obese participants may have been misdiagnosed as asthmatic. But given these participants were recruited from a specialist Respiratory Outpatient clinic, this seems unlikely. It may also be argued that the sample size of the 'laboratory-tested' group attributed to the outcomes, however, these results echo those of the 760 participants described in Chapters 3 and 4. More probable is the concept that physical activity is simply a poor predictor of aerobic fitness and BMI in childhood and adolescence and that any influence physical activity has on fitness and body composition may not appear until late adolescence or adulthood.

In terms of physical activity, and in agreement with the literature (see review by Welsh *et al.*, 2004), the severely asthmatic participants were as active as the 'school-tested' non-asthmatic and asthmatic participants described in Chapters 3 and 4. Activity monitor counts and MET values did not differ significantly when comparing data grouped according to asthma status (i.e. non-asthmatic, asthmatic, severely asthmatic – see Tables 5.10 & 5.11). However, severely asthmatic females demonstrated lower PAQ-C values when compared to 'school-tested' non-asthmatics. Given the lack of differences in their objectively measured physical activity data, this result is difficult to explain. It may be that severely asthmatic females view themselves as having a limitation to exercise as a result of their disease severity. It has previously been reported that perceived competence is associated with exercise performance in asthmatic children (Pianosi & Davis, 2004).

## Normative Data

### *Body Composition*

No gender difference in mean BMI for the severely asthmatic group was reported, however, it should be noted that sample sizes were low. This result may also be a reflection of the calculation being made over a larger age range in comparison to the BMI results presented in Chapters 3 and 4. Consistent with the asthmatic participants described in Chapter 4, around 34.3% of the sample was deemed to be overweight or obese according to the BMI cutoff points of Cole *et al.* (2000).

### *Aerobic Fitness*

No gender difference was found in mean peak $\dot{V}O_2$ values between male and female severe asthmatics. Again, however, this may be a reflection of the wider age range of the group. The GXT mean peak $\dot{V}O_2$ values reported in the present study agree with the estimated values reported in Chapters 3 and 4, as well as those of similarly-aged non-asthmatic children and adolescents from previous studies (Fink *et al.*, 1993; Armstrong *et al.*, 1995; Douard *et al.*, 1997; Armstrong *et al.*, 1999).

### *Physical Activity*

Males had a greater mean PAQ-C value in comparison to females, which is consistent with the findings reported in Chapters 3 and 4 and in agreement with the literature available for non-asthmatic children (Crocker *et al.*, 2000). Furthermore, the mean PAQ-C values for severe asthmatics are comparable to those previously reported for an asthmatic population of similar age (Toohey, 2000) as well as non-asthmatic children (Crocker *et al.*, 1997; Crocker *et al.*, 2000; Toohey, 2000; Bate, 2001).

**Concluding Remarks**

The present study demonstrates that severely asthmatic children and adolescents are able to achieve levels of aerobic fitness comparable to their non-asthmatic and trivial/mild/moderate asthmatic peers. This indicates that severe asthmatic youth should be able to train at work intensities sufficient to bring about improvements in cardio-respiratory fitness without any added functional limitation due to their disease. Therefore, it seems that if asthma is well-controlled, then it is the level of physical conditioning that is more important than the disease *per se* in determining the peak aerobic power of the individual. Asthmatics may employ an atypical breathing pattern during exercise in order to minimise dyspnoea and avoid exercise-induced asthma, although only the female group exhibited this pattern in the current study. Although Orenstein (2002) was referring to the non-asthmatic population when he stated that "In the overwhelming majority of youngsters, exercise tolerance is limited by cardiovascular and muscular factors, not the lungs", this may also be applicable to well-controlled asthmatics, regardless of severity. The current results also demonstrate that for severe sufferers, a state of *well-controlled* asthma allows them to engage in similar levels of physical activity as their non-asthmatic or less severe asthmatic peers.

The results of this chapter and Chapter 4 suggest that asthma may increase the likelihood of being overweight/obese, or that being overweight/obese may play a role in the asthmatic pathology. All young asthmatics should be encouraged to participate in regular physical activity under well-managed asthma medication, and thereby enjoy the longer term benefits expected through a reduced risk of inactivity-related degenerative disease later in life.

## Recommendations

First and foremost, the current results indicate that when properly managed, asthma, regardless of severity level, should not prevent children and adolescents from leading active lives or achieving ‘normal’ levels of aerobic fitness. Clinically, this information may aid health professionals and assist in the delivery of more effective treatment, especially in terms of exercise prescription for asthma management plans. However, these findings also suggest an additive risk of overweight/obesity in children and adolescents with asthma, or that overweight/obesity may precede the asthmatic condition. These data therefore imply that special consideration should be afforded to children and adolescents who have diagnoses of both asthma and overweight/obesity. Considering the inverse relationship between aerobic fitness and markers of increased body fat reported here, information sheets regarding exercise involvement could be distributed by consulting physicians upon diagnosis. Moreover, regular physical activity evaluations made during follow-up visits may greatly benefit disease management. However, in order to optimise treatment, consulting physicians may be required to develop individually tailored exercise programs as part of the overall course of therapy.

The prevalence of overweight/obesity in any large sample of children is cause for concern. The current rates are consistent with recently reported data for similarly aged children and adolescents within Australia, confirming an insidious rise in recent decades. The health risks associated with overweight/obesity during childhood and adolescence justify widespread efforts toward prevention and intervention. Although the relationship between physical activity and excess body mass in youth remains controversial, exercise involvement, and indeed aerobic fitness, appear to have a role to play. Controlled exercise programs are likely to be a good starting point, however, they may be best adhered to with gentle progressions, simple activities and with an emphasis on participation at a convenient cost and time. In a more broad sense, the current situation warrants an aggressive approach by those in position to affect public health policy, make environmental planning decisions and implement large-scale educational opportunities regarding physical activity. Moreover, the role of schools in providing physical activity education and opportunities is also critical.

One way to affect public health policy change would be to provide key decision makers with accurate advice on the benefits associated with physical activity and aerobic fitness as well as the risks associated with overweight/obesity. Although the large convenient sample recruited for this study provides a firm base of evidence for the relationships between activity, fitness and body fat among youth, field-based tests such as those used in this thesis have limitations, and hence, further work is required. Stratified random samples, and randomised controlled trials using more robust methodologies would likely provide the next order of evidence required to implement widespread change. Moreover, the association between asthma and overweight/obesity requires further exploration in order to gain a better understanding of the relationship, and to advance therapeutic strategies among children and adolescents with these conditions.

Concisely, all youth, asthmatic and non-asthmatic alike, should be aiming to regularly participate in physical activity and achieve their best possible level of aerobic fitness, in attempt to avoid future inactivity related morbidities and benefit from the associated health advantages.

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# Appendix A Bioelectrical Impedance and Anthropometric Measurements of Body Composition

## A.1 Introduction

The prevalence of overweight and obesity among children and adolescents continues to escalate globally (Magarey *et al.*, 2001; Viguie *et al.*, 2002; Heude *et al.*, 2003) Elevated body fat composition has been independently linked to various diseases including coronary heart disease (Freedman *et al.*, 2004), hypertension (Ogden *et al.*, 2003), non-insulin dependent diabetes mellitus (Falkner & Michel, 1999) and asthma (Tantisira & Weiss, 2001). Obesity is now strongly believed to be a key modulator of the metabolic syndrome; a clustering of metabolic abnormalities associated with an increased risk of atherosclerotic cardiovascular disease (Berenson, 2005; Weiss & Caprio, 2005). These metabolic abnormalities include insulin resistance, hypertension, dyslipidemia, type 2 diabetes and abnormal glucose metabolism (Vanhala *et al.*, 1998; Vanhala *et al.*, 1998; Weiss *et al.*, 2004). The prevalence of the metabolic syndrome is high among obese children and adolescents, and is exacerbated with worsening obesity (Weiss *et al.*, 2004).

A plethora of adult-related diseases are postulated to have their origins in childhood and adolescence (Freedman *et al.*, 2001). As such, identifying children at risk of overweight/obesity may lead to early intervention resulting in the prevention of adult obesity, the metabolic syndrome and cardiovascular risk (Vanhala *et al.*, 1998; Vanhala *et al.*, 1998).

In addition, a low body fat composition has been associated with cardiovascular disease (Higashi *et al.*, 2003) and osteoporosis (Ravn *et al.*, 1999).

Accurate measurement of body composition is therefore vital in understanding the etiology and pathology of many diseases, in conjunction with identifying associated risk factors. Presently, the four-compartment model of fat mass, total body water, bone mineral mass and residual mass is considered to be the gold standard for the determination of body composition in both adults (Withers *et al.*, 1998) and children (Wells *et al.*, 1999). Though highly accurate, the techniques used to obtain these components (hydrodensitometry, deuterium dilution and dual energy x-ray absorptiometry) may not be appropriate at times for children and are expensive, time-consuming and impractical for epidemiological investigations involving field testing (Mast *et al.*, 2002). However, assessments of body composition from body mass index (BMI) (Pietrobelli *et al.*, 1998), sum of skinfolds (SS) (Lohman *et al.*, 2000) and bioelectrical impedance analysis (BIA) (Boot *et al.*, 1997; Casanova Roman *et al.*, 2004) can satisfy the requirements for field testing within acknowledged limitations.

Validation studies involving the comparison of BMI, sum of skinfolds and BIA to 'reference methods' (i.e. hydrodensitometry, DEXA) have previously occurred in children and adolescents with contradictory results. While some studies support the use of BIA in the field (Boot *et al.*, 1997; Casanova Roman *et al.*, 2004), others suggest BIA is the least acceptable method of body composition assessment available and should not be used (Bray *et al.*, 2002; Fors *et al.*, 2002; Horlick *et al.*, 2002; Eisenmann *et al.*, 2004). Similarly, the use of BMI and sum of skinfolds as techniques for estimating body composition in the field has been questioned by several groups (Deurenberg *et al.*, 1990; Pietrobelli *et al.*, 1998; Dietz & Bellizzi, 1999; Lohman *et al.*, 2000).

While some lack of agreement between two different methods of measurement is inevitable, what is most important is the amount by which the methods disagree, and whether the two methods are interchangeable. How far apart measurements can be without affecting clinical interpretation depends on the use to which the results are put, and is therefore a question of clinical judgement. Statistical methods cannot always answer such questions, because methods aligned with one purpose may not adequately agree with another. Ideally, satisfactory agreement should be defined in advance.

A technique has been developed for such analysis which involves a graphical representation of the data, a calculation of the mean difference between measurements, and '95% limits of agreement' (Bland & Altman, 1986). The 95% limits of agreement define the range within which most differences between measurements by the two methods will lie. Furthermore, the decision about what is acceptable agreement between methods is a clinical one. To use an example, if measurements of body fat between two apparatus differed by less than 1% with respect to body fat then this may not affect clinical management. However, 95% limits of agreement, or, differences between the two devices of 10% with respect to body fat would most likely affect clinical management and the two devices could not be used interchangeably. In addition to Bland-Altman analysis, Pitman's test for a difference in variance can determine whether alternate measurements of the same quantity demonstrate comparable variability about their mean.

A key aim of this thesis was to describe normative body composition data for a convenient yet large sample of school children from Melbourne, Australia. However, it became clear during preliminary statistical analysis that values for %BF as estimated from the sum of skinfolds and BIA may be significantly different. In order to avoid erroneous and perhaps misleading results in Chapters 3 and 4, an investigation into the variability between body composition estimates was conducted. Specifically, the key aims of this analysis were to determine the variance of both body composition methods, and to determine whether each method would be suitable for use in the Chapters 3 and 4. Given the sum of skinfolds (SS) and BIA are estimates of %BF, while BMI is an index of a different order, Bland-Altman analyses involving measurements of BMI were not applied.

## A.2 Methodology

### A.2.1 Participants

Data presented in this chapter were collected from non-asthmatic and asthmatic 'school-tested' participants (n=760).

### A.2.2 Procedure

#### A.2.2.1 Body Mass Index

Height was recorded to the nearest 0.1 cm without shoes using a portable stadiometer (Seca Model 214, Hamburg, Germany). Weight was measured in minimal clothing, without shoes, to the nearest 0.1 kg using digital scales (Tanita BWB 600, Tanita Corp, Tokyo). The standard equation (weight (kg)/height$^2$ (m)) was employed to calculate BMI.

#### A.2.2.2 Bioelectrical Impedance Analysis and Skinfold Measurement

Bioelectrical impedance was measured by a Biodynamics® Model 310e analyser (Biodynamics Corporation, Seattle, Washington), while Harpenden skinfold calipers (British Indicators Ltd, St Albans, Hertfordshire) were used to measure skinfold thicknesses at the biceps, triceps, subscapular and suprailiac sites as recommended by Durnin and Rahaman (1967). Detailed information on the testing protocols for skinfold and bioelectrical impedance measurements are provided in Chapter 2, Section 2.2.2, and one well-practiced operator performed all skinfold measurements to avoid errors associated with inter-tester reliability. Additionally, the standard error of the estimate for skinfold measurements equated to 2.3 %BF.

### A.2.3 Data Management

Data were grouped according to grade and gender.

### A.2.4 Statistical Analysis

Statistical analysis was performed using *Stata* Version 8.0 (Stata Corporation, Texas, USA). Descriptive data were reported as mean and standard deviation. Mean comparisons were made using Student's paired *t*-test with significance levels set at $p<0.05$. Bland-Altman analyses were used to compare %BF values derived from the sum of skinfolds (SS %BF) and %BF values derived from bio-electrical impedance analysis (BIA %BF) among grades and gender group. This included Pitman's test for a difference in variance.

## A.3 Results

### A.3.1 Participant Characteristics

Seven-hundred and sixty grade 5 and 8 children and adolescents aged 10 to 14 years were recruited from government, independent and Catholic schools from metropolitan Melbourne, Australia. Participant characteristics are shown in Table A.1.

**Table A.1 Participant characteristics of 10-14 year old non-asthmatic and asthmatic children and adolescents**

| | **Grade 5 Male** (n=223) | **Grade 5 Female** (n=168) | **Grade 8 Male** (n=165) | **Grade 8 Female** (n=204) |
|---|---|---|---|---|
| **Age (years)** | 10.93 ± 0.50 | 10.90 ± 0.41 | 13.50 ± 0.40 | 13.82 ± 0.48 |
| **Height (cm)** | 146.6 ± 6.4 | 146.2 ± 7.3 | 163.4 ± 9.1 | 161.2 ± 6.3 |
| **Mass (kg)** | 40.2 ± 8.8 | 39.4 ± 7.6 | 55.2 ± 12.4 | 55.9 ± 11.1 |
| **BMI ($kg/m^2$)** | 18.63 ± 3.20 | 18.33 ± 2.63 | 20.60 ± 3.53 | 21.50 ± 3.70 |

Mean ± SD

## A.3.2 Body Composition Data

Mean SS %BF and BIA %BF results are shown in Table A.2. Within each grade and gender group, mean SS %BF and BIA %BF results were significantly different. Furthermore, for all groupings, BIA %BF demonstrated the greatest standard errors and 95% confidence intervals.

**Table A.2 Body composition characteristics of 10-14 year old non-asthmatic and asthmatic children and adolescents**

| Group | Grade 5 Male (n=223) | Grade 5 Female (n=168) | Grade 8 Male (n=165) | Grade 8 Female (n=204) |
|---|---|---|---|---|
| **SS %BF** | 22.93 ± 5.90 (22.16 to 23.71) | 27.87 ± 4.40 (27.20 to 28.50) | 21.81 ± 5.84 (20.89 to 22.72) | 30.54 ± 4.16 (29.96 to 31.12) |
| **BIA %BF** | 22.30 ± 6.40† (21.70 to 23.37) | 24.20 ± 5.50† (23.34 to 25.01) | 20.94 ± 7.03† (19.75 to 21.94) | 29.55 ± 5.74† (28.81 to 30.29) |

Mean ± SD (95% CI)

† significantly different from SS %BF value within grade and gender group ($p<0.05$)

## A.3.3 Bland-Altman analyses

A Bland-Altman plot of SS %BF and BIA %BF values for Grade 5 males is displayed in Figure A.1. That is, plots of the difference of the paired variables versus their average.

Bland-Altman analysis results are shown in Table A.3. Pitman's test of difference in variance revealed that the two variables had significantly different variances.

**Table A.3 Bland-Altman analysis for non-asthmatic and asthmatic participants**

| | Grade 5 Male (n=223) | Grade 5 Female (n=168) | Grade 8 Male (n=165) | Grade 8 Female (n=204) |
|---|---|---|---|---|
| **Limits of Agreement** | -6.40 to 7.03 | -4.50 to 11.85 | -6.00 to 7.80 | -3.14 to 5.14 |
| **Mean Difference (95% CI)** | 0.63 (0.200 to 1.150) | 3.67 (3.05 to 4.30) | 0.90 (0.42 to 1.70) | 1.00 (0.77 to 1.82) |
| **Range** | 14.90 to 35.20 | 16.90 to 37.20 | 13.85 to 42.20 | 18.50 to 38.50 |
| **Pitman's Test of Difference in Variance** | $p = 0.03$ | $p = 0.001$ | $p < 0.0001$ | $p < 0.0001$ |

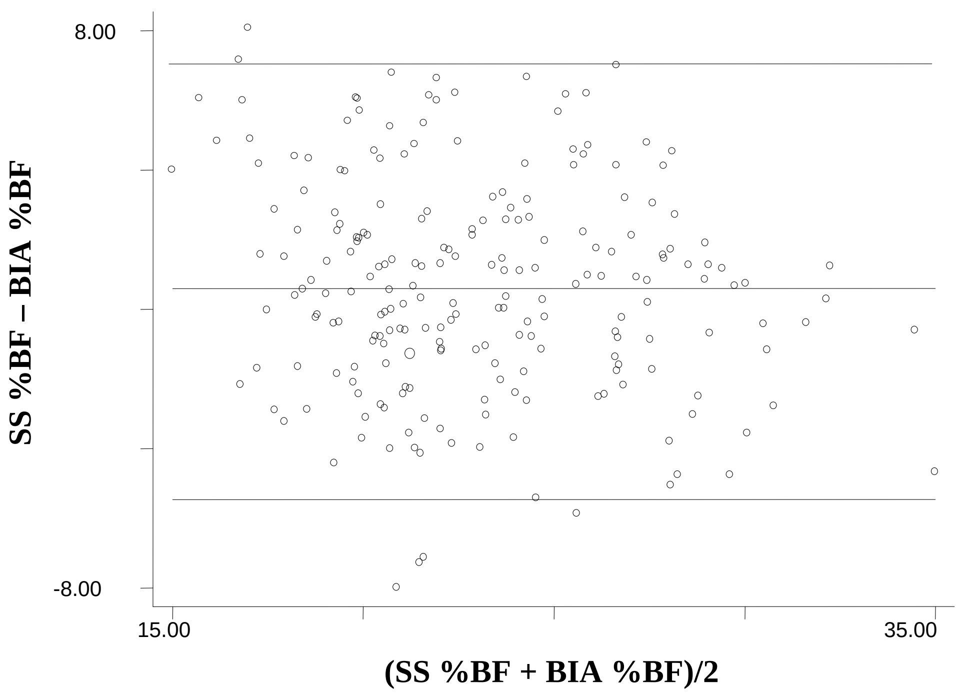



**Figure A.1 Bland-Altman plot for SS %BF and BIA %BF in grade 5 males**

Comparison of estimated percentage body fat values from skinfold measurement data and bioelectrical impedance analysis data in 222 grade 5 males aged 10.93 ± 0.03 years.

A Bland-Altman plot of SS %BF and BIA %BF values for Grade 5 females is displayed in Figure A.2 and Bland-Altman analysis results are shown in Table A.3. Again, a Pitman's test of difference in variance revealed that the two variables were significantly different in terms of variance.

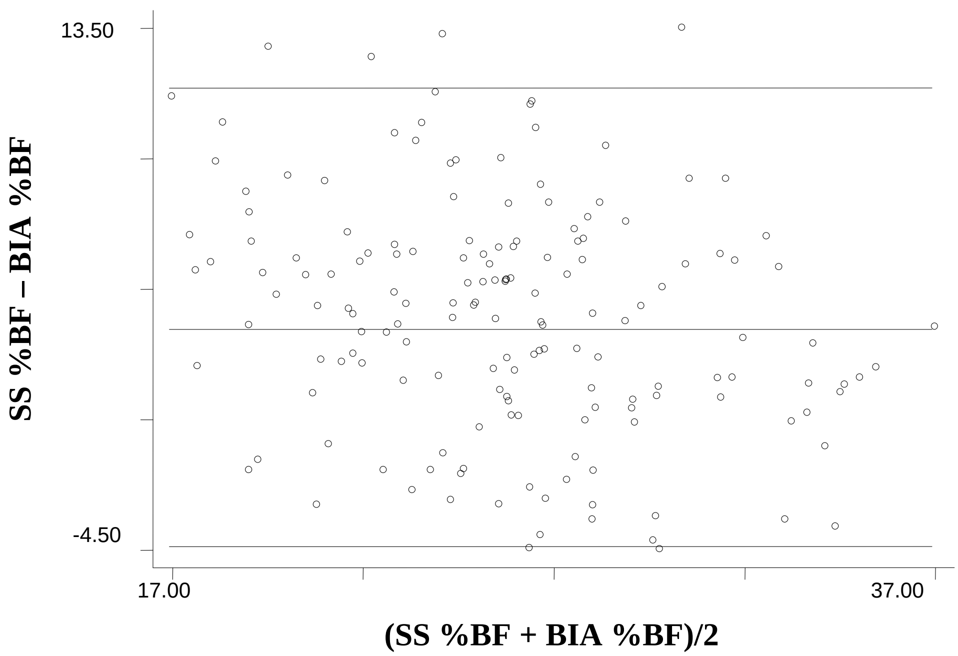



**Figure A.2 Bland-Altman plot for SS %BF and BIA %BF in grade 5 females**

Comparison of estimated percentage body fat values from skinfold measurement data and bioelectrical impedance analysis data in 167 grade 5 females aged 10.90 ± 0.03 years.

Bland-Altman plots of SS %BF and BIA %BF values for Grade 8 males and females are displayed in Figures A.3 and A.4, respectively. Moreover, results from Bland-Altman analyses are shown in Table A.3. For both males and females, SS %BF and BIA %BF values demonstrated significantly different variances.

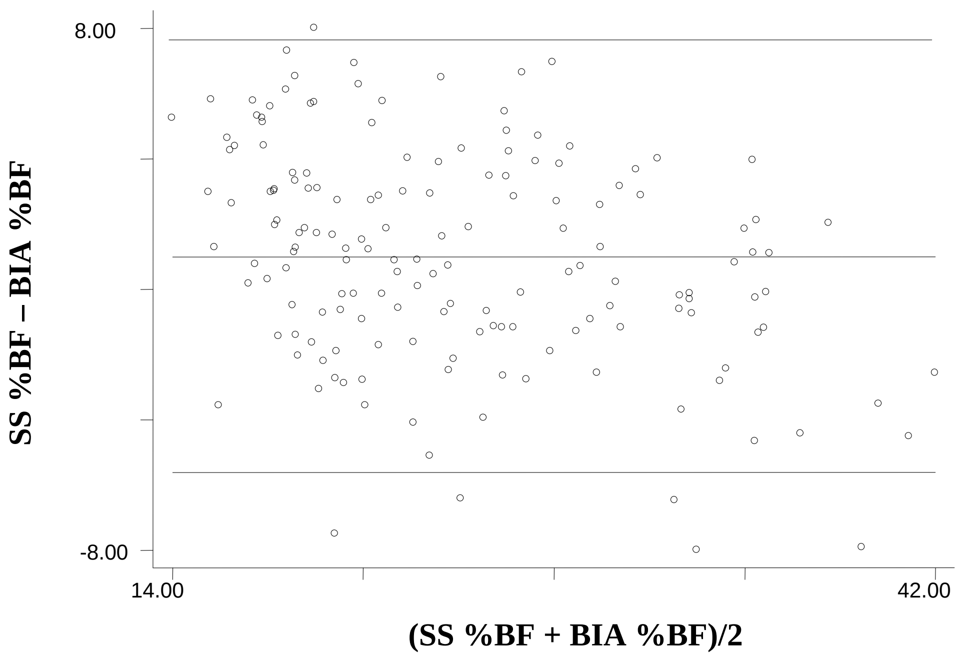



**Figure A.3 Bland-Altman plot for SS %BF and BIA %BF in grade 8 males**

Comparison of estimated percentage body fat values from skinfold measurement data and bioelectrical impedance analysis data in 161 grade 8 males aged 13.50 ± 0.03 years.

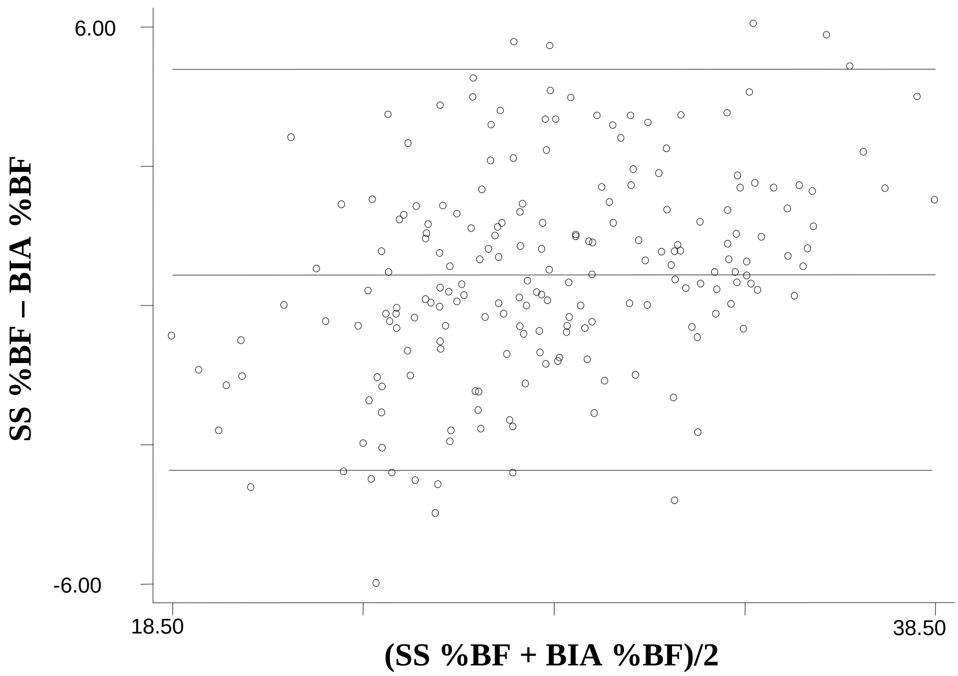



**Figure A.4 Bland-Altman plot for SS %BF and BIA %BF in grade 8 females**

Comparison of estimated percentage body fat values from skinfold measurement data and bioelectrical impedance analysis data in 201 grade 8 females aged 13.82 ± 0.03 years.

## A.4 Discussion

Of the two body composition methods analysed, BIA was found to have the greatest variability. When compared to the sum of skinfold results, BIA demonstrated greater standard deviations and greater 95% confidence intervals. Some lack of agreement between different methods of measurement is inevitable. However, the important question is whether these differences are large enough to lead to significantly different results. Pitman's test for a difference in variance revealed that the two methods had a significantly different variance, and Bland-Altman analyses revealed unacceptably wide limits of agreement. That is, the results of each method were not interchangeable. Specifically, the limits of agreement ranged from approximately 8 to 16 %BF (see Table A.3).

Without comparison to a reference method such as DEXA or hydrodensitometry, it is not possible to propose which of the two methods is the most accurate or to suggest whether an over- or under-estimation is taking place in either method. However, among the children recruited for this study, BIA demonstrated the greatest variability. One operator performed all of the BIA measurements in this study and, as such, inter-operator variability does not explain this result. One possible biological explanation for the greater variability involves previously reported patterns of diurnal variation in bioresistance, resultant from changes in fluid and electrolyte distribution following the consumption of a meal (Deurenberg *et al.*, 1989; Slinde & Rossander-Hulthen, 2001). Slinde and Rossander-Hulthen (2001) observed significantly lower levels of bioresistance among 18 healthy adults (31.5 ± 11.7 years) following the ingestion of a meal. Consistent decreases in bioresistance were observed for two hours after the first meal of the day and for four hours after the second meal, indicative of an additive effect. Slinde and Rossander-Hulthen (2001) concluded that BIA should be carried out in the fasting state and that the ingestion of a meal could significantly affect %BF results. Although for the current study around 70% of measurements were performed in the morning, it was not possible to regulate participants' eating habits. As such, it was conceded that part of the variability in BIA may be due to this effect. The limitation of being unable to regulate participants' eating habits is unlikely to have affected skinfold results.

In addition, the BIA apparatus used in the current study was a single frequency device, factory fitted with an equation for estimating %BF that could not be modified. Despite being more cost effective, single frequency devices are less precise when compared with multiple frequency models (Paton *et al.*, 1998). Thus the frequency capacity may have also played a role in the variability of BIA results.

When examining the existing literature, Eisenmann *et al*. (2004) suggested that BIA had a limited utility in the estimation of body composition and proposed that BMI and sum of skinfolds were likely to be more useful. Furthermore, Bray *et al*. (2002) concluded that BIA was the least acceptable of five methods (including skinfold measurement) for the determination of body fat. In addition, Fors *et al*. (2002) reported that BIA overestimated fat mass in lean subjects.

The sum of skinfolds approach is also not without methodological limitation. For example, the ability of the operator to accurately locate the recommended skinfold sites is of major importance and a source for potential error. Moreover, inter-operator variability is another source of error when using sum of skinfold assessments. However, these limitations were reduced in the current investigation because only one operator performed all skinfold measurements and had previous paediatric testing experience of around 2000 children and adolescents. Notably, the standard error of the estimate for skinfold measurements equated to 2.3 %BF.

Additionally, the sum of skinfold method relies on several assumptions. One is that the method is an accurate measure of subcutaneous fat, and another is the assumption that there is a good relationship between subcutaneous fat and total body fat. Intermuscular fat, intramuscular fat, and fat in the abdominal and thoracic cavities are not captured by skinfold measurement (Lohman, 1981). Lohman (1981) analysed several potential sources of error in the skinfold method, including variation in subcutaneous to total fat, variation in skinfold thickness to subcutaneous fat, and technical error in the skinfold measurement. From these variations, Lohman theorised that the total error of estimation (biological and technical) of fat content from skinfold thicknesses was 3.3 %BF. Such errors should be taken into account when considering the current results.

Although laboratory-based methods for the determination of body composition including DEXA and hydrodensitometry are generally more accurate than field-based methods (see Section 1.2.2), they are also more expensive, more time consuming, and require a higher degree of technical training and skill. Several factors such as cost, ease of operation, operator training and skill, subject co-operation and comfort, the number of participants and the time available for assessment all need to be considered prior to selecting a method for body composition assessment. For the current study of 760 participants, it was not feasible to undertake any superior techniques (e.g. DEXA, hydrodensitometry) for the assessment of body composition and, as such, measurements of skinfolds and BIA were most practical.

Despite concerns regarding the validity of the data, statistical analyses revealed that %BF values derived from BIA displayed similar relationships with measures of physical activity and aerobic fitness as those observed for %BF values derived from skinfold measurements and reported in Chapters 3 and 4. However, given that BIA should have been conducted in the fasting state for optimal results, and the fact that BIA data displayed greater variability and significantly different mean values compared to skinfold data, it was decided that values used to represent the %BF of the sample investigated should be that from the SS testing.

**Concluding Remarks**

In comparison to sum of skinfolds, BIA demonstrated a greater variability in the assessment of body composition in the children and adolescents of this study. Moreover, Bland-Altman analysis revealed unacceptably wide limits of agreement. Without a gold standard technique such as DEXA or hydrodensitometry to use as a reference, it was not possible to ascertain which of the two field-based methods was most accurate for assessing %BF in this study. However, %BF estimates from BIA produced significantly different values from those derived by sum of skinfolds within each grade and gender group and displayed the greatest variance among these participants. As such, only the results stemming from the sum of skinfold measurements were used when expressing %BF in Chapters 3 and 4.

# Appendix B: Standard Informed Consent

STANDARD <u>INFORMED CONSENT</u>
FOR <u>PARENT / GUARDIAN</u> TO GIVE CONSENT FOR THEIR CHILD TO PARTICIPATE IN A RESEARCH PROJECT.

| **Project No:** 99003 B |
|---|

**<u>Lay title of the project:</u>**
**Physical activity and fitness of asthmatic children**

**Principal Investigator(s):** Dr Ric Roberts, Dr Colin Robertson, Justin Kemp, Liam Welsh.

**Brief outline of research including benefits, possible risks, inconveniences and discomforts.**
We are interested in finding out about the relationship between physical (aerobic) fitness and the amount of physical activity your child gets. We want to test children both with and without asthma. To do this we are asking you to complete an asthma screening questionnaire and your child at school to fill out a questionnaire about physical activity in the last week. To estimate aerobic fitness we would like your child to complete a run in which we measure the distance covered in 6 minutes. During the run your child will wear a *POLAR* heart rate monitor (an elastic strap around the chest with a wristwatch recorder) so that we can measure heart rate during the run. Before and after the run your child will be asked to blow into a machine while wearing a noseclip to see if the effort has affected breathing. Finally we may ask your child to wear an activity monitor for a continuous 5-7 day period, including the weekend. This is a device to measure movement (that sits in a pouch on a belt around the waist) during the daytime. In this way we will be able to relate the level of aerobic fitness with the amount of physical activity your child achieves.

I (Parent/Guardian name)______________________________________
Parent / Guardian of (child's name)_______________________________
voluntarily consent to him / her taking part in the above titled Research Project explained to me by Dr Roberts.

**<u>I have received a Parent/Guardian Information Statement</u> to keep and I fully understand the purpose, extent and possible effects of his/her involvement. I have been asked if I would like a family member or friend with me while the project is explained.**

I understand that if I refuse to consent, or withdraw my child at any time without explanation, this will not affect my child's access to the best available treatment and care from The Women's and Healthcare Network (The Royal Women's Hospital OR The Royal Children's Hospital).
**I understand I will receive a copy of this consent form.**

PARENT GUARDIAN SIGNATURE__________________________ __________
Date

WITNESS ________________________________________________________ __________
Name Relationship

WITNESS SIGNATURE _____________________________________________ __________
Date

RESEARCHER'S SIGNATURE________________________________________ __________
Date

# Appendix C: Asthma Severity Questionnaire (ASQ)

**RESPIRATORY SYMPTOMS QUESTIONNAIRE AND SCORING**

**Student's Name _______________ Class_________________ Date of Birth_____________**

***<u>THE FOLLOWING QUESTIONS RELATE TO THE LAST 2 (TWO) MONTHS ONLY:</u>***

1) ***<u>In the last 2 months</u>***, how often did you have symptoms which required you to take Ventolin or Bricanyl?

| | | | | | |
|---|---|---|---|---|---|
| ***Daily*** | **4** | ***Weekly*** | **3** | ***Monthly*** | **2** |
| ***Less than monthly*** | **1** | ***Never*** | **0** | ***Don't Know*** | **9** |

2) ***<u>In the last 2 months</u>***, how often did you wake at night with cough or wheezing?

| | | | |
|---|---|---|---|
| ***Most nights*** | **4** | ***1-3 nights per week*** | **3** |
| ***Less than 1 night per week*** | **2** | ***Only with episodes*** | **1** |
| ***Never*** | **0** | ***Don't Know*** | **9** |

3) ***<u>In the last 2 months</u>***, how often was your wheezing troublesome first thing in the morning?

| | | | |
|---|---|---|---|
| ***Most mornings*** | **4** | ***1-3 mornings per week*** | **3** |
| ***Less than 1 morning/ week*** | **2** | ***Only with episodes*** | **1** |
| ***Never*** | **0** | ***Don't Know*** | **9** |

4) ***<u>In the last 2 months</u>***, has wheezing ever been severe enough to limit your speech to only one or two words at a time between breaths?

| | | | | | |
|---|---|---|---|---|---|
| ***Yes*** | **4** | ***No*** | **0** | ***Don't Know*** | **9** |

5) ***<u>In the last 2 months</u>***, how often were your activities affected or limited by wheeze or shortness of breath while at home or playing with other children?

| | | | | | |
|---|---|---|---|---|---|
| ***Daily*** | **4** | ***Weekly*** | **3** | ***Monthly*** | **2** |
| ***Less than monthly*** | **1** | ***Never*** | **0** | ***Don't Know*** | **9** |

6) ***<u>In the last 2 months,</u>*** how often were your sporting activities* affected or limited by cough or wheeze or shortness of breath?

| | | | | | |
|---|---|---|---|---|---|
| ***Daily*** | **4** | ***Weekly*** | **3** | ***Monthly*** | **2** |
| ***Less than monthly*** | **1** | ***Never*** | **0** | ***Don't Know*** | **9** |

*<u>Note</u>: Sport activities include both organised sport and physical education. If no sport activities are provided at school, the question applies to out of school activities.

7) ***<u>In the last 2 months</u>***, have you taken any medication (medicines/pills/puffers) for wheezing or asthma?

| | | | |
|---|---|---|---|
| ***Yes*** | **1** | ***No*** | **0** |

8) ***<u>Outside school hours</u>***, how often do you usually exercise in your free time so much that you get out of breath or sweat?

| | | | | | |
|---|---|---|---|---|---|
| ***Daily*** | **5** | ***More than 3 times a week*** | **4** | ***Twice a week*** | **3** |
| ***Once a week*** | **2** | ***About once a fortnight*** | **1** | ***About once a month*** | **1** |
| ***Less than monthly*** | **0** | | | | |

9) ***<u>Outside school hours</u>***, how many hours a week do you usually exercise in your free time so much that you get out of breath or sweat?

| | | | |
|---|---|---|---|
| ***None*** | **0** | ***1-2 hours*** | **1** |
| ***2-3 hours*** | **2** | ***3-4 hours*** | **3** |
| ***5-6 hours*** | **4** | ***7 hours or more*** | **5** |

# Appendix D: Six-Minute Running Test Equations for Predicted Peak $\dot{V}O_2$


Consultant's Name: Kris Jamsen
RCH Contact No: 9345 7957
E-mail: kris.jamsen@mcri.edu.au


## CEB Consultancy Report

| | |
|---|---|
| Project Title: | Relationship between aerobic fitness and distance run in 6 minutes |
| Project Number: | 485 |
| Project Department: | Respiratory Medicine |
| Client Names: | Ric Roberts |

**Caveat**
Consulting reports are preliminary working papers and should not be used for submission of manuscripts without discussion with the author.

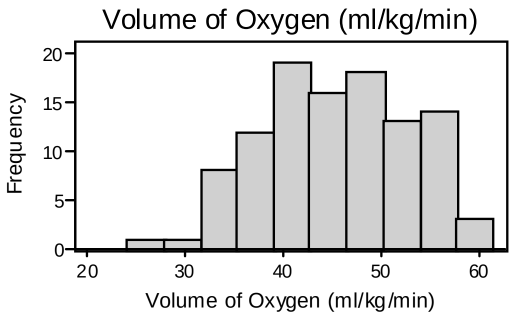
**Background**
Investigator is interested in assessing the relationship between aerobic fitness (measured by volume of oxygen, where higher values indicate better fitness) and distance run in six minutes. Investigator is also interested in taking into account age and gender.

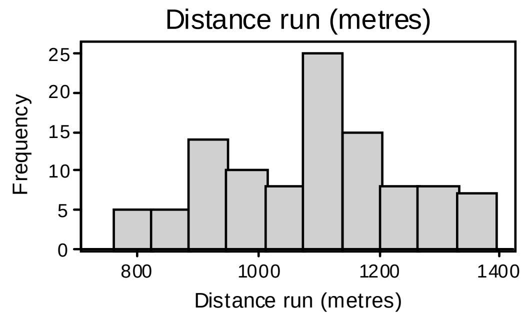
**Data**
One record per person, and there are a total of 105 records.

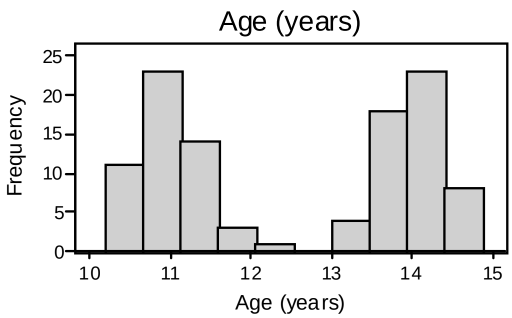
**Analysis**
Linear regression was used to examine the relationship between volume of oxygen (outcome) and distance run in six minutes, as well as to assess the possibility of interactions between distance run and gender (i.e. genders having substantially different slopes) as well as distance run and age (i.e. the slope differing substantially for different levels of age). Evidence for interaction was further assessed using the likelihood ratio test.

**Results**
The figure below displays the distributions of volume of oxygen, distance run in six minutes and age. Summaries of these variables are also given below, along with a summary of

gender. Age was dichotomized into up to 12.5 years and greater than 12.5 years, and the numbers in each group are displayed below.




Volume of Oxygen (ml/kg/min)

| | Percentiles | Smallest | | |
|---|---|---|---|---|
| 1% | 31.1 | 24.12 | | |
| 5% | 34 | 31.1 | | |
| 10% | 35.4 | 33 | Obs | 105 |
| 25% | 40.2 | 33.85 | Sum of Wgt. | 105 |
| 50% | 45.5 | | Mean | 45.54771 |
| | | Largest | Std. Dev. | 7.487504 |
| 75% | 51.3 | 57.5 | | |
| 90% | 55.4 | 60.3 | Variance | 56.06271 |
| 95% | 56.68 | 60.9 | Skewness | -.0957762 |
| 99% | 60.9 | 61.5 | Kurtosis | 2.485965 |

Distance run (metres)

| | Percentiles | Smallest | | |
|---|---|---|---|---|
| 1% | 770 | 760 | | |
| 5% | 830 | 770 | | |
| 10% | 890 | 770 | Obs | 105 |
| 25% | 970 | 780 | Sum of Wgt. | 105 |
| 50% | 1100 | | Mean | 1083.19 |
| | | Largest | Std. Dev. | 153.6528 |
| 75% | 1180 | 1340 | | |
| 90% | 1300 | 1340 | Variance | 23609.19 |
| 95% | 1330 | 1390 | Skewness | -.1073338 |
| 99% | 1390 | 1390 | Kurtosis | 2.352353 |

```
          Age (years)
-------------------------------------------------------------
      Percentiles      Smallest
 1%         10.3           10.2
 5%         10.4           10.3
10%         10.6           10.3       Obs                 105
25%           11          10.37       Sum of Wgt.         105

50%           13                      Mean           12.52181
                        Largest       Std. Dev.       1.57686
75%           14           14.7
90%         14.3           14.7       Variance       2.486488
95%        14.57           14.7       Skewness      -.0307028
99%         14.7          14.86       Kurtosis       1.232216
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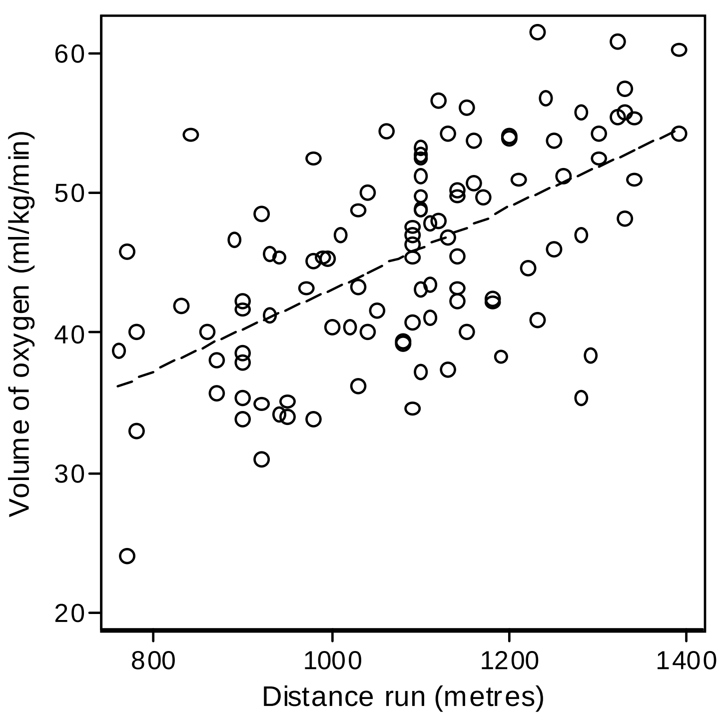
```
     Gender |      Freq.     Percent        Cum.
------------+-----------------------------------
       Male |         48       45.71       45.71
     Female |         57       54.29      100.00
------------+-----------------------------------
      Total |        105      100.00
```

```
   Age group |      Freq.     Percent        Cum.
-------------+-----------------------------------
<=12.5 years |         52       49.52       49.52
 >12.5 years |         53       50.48      100.00
-------------+-----------------------------------
       Total |        105      100.00
```

The figure below displays volume of oxygen vs distance run in six minutes with the fitted regression line. The regression output is also displayed below.

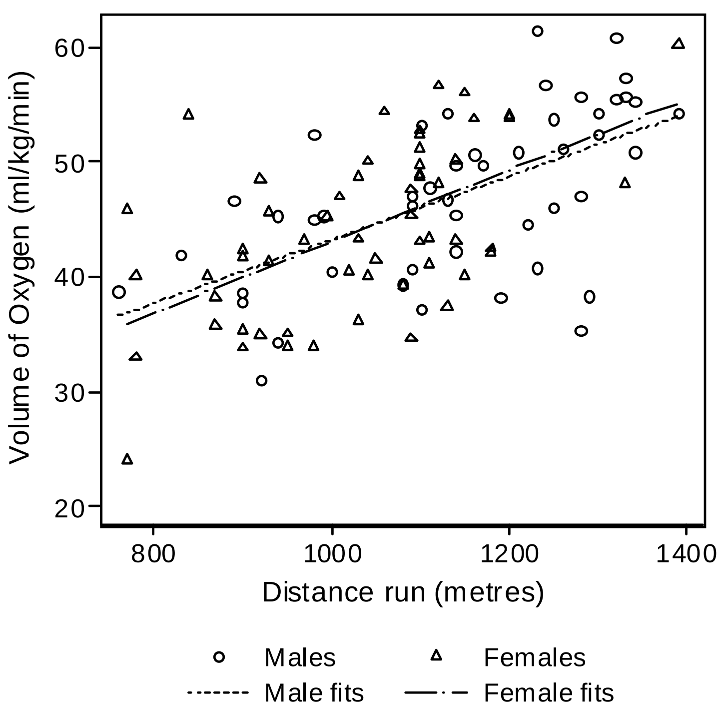


```
      Source |       SS       df       MS              Number of obs =     105
-------------+------------------------------           F(  1,   103) =   57.63
       Model |  2091.80162     1  2091.80162           Prob > F      =  0.0000
    Residual |  3738.72023   103  36.2982547           R-squared     =  0.3588
-------------+------------------------------           Adj R-squared =  0.3525
       Total |  5830.52185   104  56.0627101           Root MSE      =  6.0248

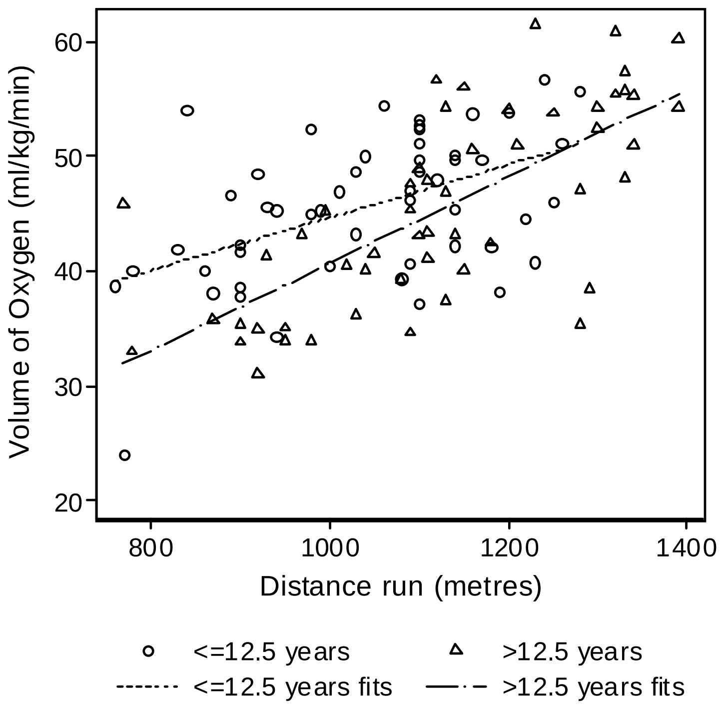
------------------------------------------------------------------------------
         vo2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    six_mind |   .0291879   .0038449     7.59   0.000     .0215624    .0368134
       _cons |   13.93165   4.206062     3.31   0.001     5.589915    22.27338
------------------------------------------------------------------------------
```

Thus the linear model fitted implies that for each extra metre of distance run, the average volume of oxygen increases by 0.029 ml/kg/min, and there is strong evidence for association.

Below is the plot of volume of oxygen vs. distance run in six minutes by gender. The likelihood ratio test was performed to assess the possibility of an interaction between gender and distance run (i.e. that genders had substantially different slopes) and there was little evidence for difference (p=0.67).



Below is the plot of volume of oxygen vs. distance run in six minutes by age group. The likelihood ratio test was performed to assess the possibility of an interaction between age group and distance run (i.e. that the groups had substantially different slopes). There was borderline evidence for difference (p=0.05), however it was not convincing enough to include the interaction term in the final model.




Below is the output from the final model, where the relationship between volume of oxygen and distance run in six minutes is adjusted for gender and age group (no interactions).

```
      Source |       SS       df       MS              Number of obs =     105
-------------+------------------------------           F(  3,   101) =   22.14
       Model |  2313.32172     3  771.107239           Prob > F      =  0.0000
    Residual |  3517.20013   101  34.8237637           R-squared     =  0.3968
-------------+------------------------------           Adj R-squared =  0.3788
       Total |  5830.52185   104  56.0627101           Root MSE      =  5.9012

------------------------------------------------------------------------------
         vo2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 _Iage_grp_2 |   -3.14857   1.249316    -2.52   0.013    -5.626877   -.6702626
  _Igender_2 |   1.062682   1.294637     0.82   0.414    -1.505529    3.630893
    six_mind |   .0332147   .0043223     7.68   0.000     .0246405     .041789
       _cons |   10.58221   4.856275     2.18   0.032     .9486695    20.21576
------------------------------------------------------------------------------
```

Thus the linear model fitted implies that for each extra metre of distance run, the average volume of oxygen increases by 0.033 ml/kg/min for any given age group or gender, and there is strong evidence for association. On average older patients use approximately 3.15 ml/kg/min less oxygen than younger patients for any given distance or gender, and there is some evidence for difference. Also, females on average use approximately 1.06 ml/kg/min more oxygen than males for any given distance or age group, however there is little evidence for difference.

**Documentation**
Calculations were done in Stata 9.0.

# Appendix E: Physical Activity Questionnaire for Children (PAQ-C)

**Date:** / / **Name:**________________________**Sex:** M ☐ F ☐ **School** _________________
**DOB:** / /

We are trying to find out about your level of Physical Activity from the last 7 days (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you feel out of breath, like tag, skipping, running, climbing and others.

Remember:
A. There are no right or wrong answers - this is not a test.
B. Please answer all the questions as honestly and accurately as you can – this is very important.

**1. PHYSICAL ACTIVITY IN YOUR SPARE TIME**
**Have you done any of the following activities in the past 7 days (last week)? If yes, how many times?**

**Tick only one box per row**

| | 1-2 | 3-4 | 5-6 | 7 times or more |
|---|---|---|---|---|
| Netball | ☐ | ☐ | ☐ | ☐ |
| Roller Blading | ☐ | ☐ | ☐ | ☐ |
| Chasing games | ☐ | ☐ | ☐ | ☐ |
| Walking for Exercise | ☐ | ☐ | ☐ | ☐ |
| Bicycling | ☐ | ☐ | ☐ | ☐ |
| Jogging or Running | ☐ | ☐ | ☐ | ☐ |
| Aerobics | ☐ | ☐ | ☐ | ☐ |
| Swimming | ☐ | ☐ | ☐ | ☐ |
| Baseball, Softball | ☐ | ☐ | ☐ | ☐ |
| Dance | ☐ | ☐ | ☐ | ☐ |
| Football | ☐ | ☐ | ☐ | ☐ |
| Gymnastics | ☐ | ☐ | ☐ | ☐ |
| Skateboarding | ☐ | ☐ | ☐ | ☐ |
| Soccer | ☐ | ☐ | ☐ | ☐ |
| Hockey | ☐ | ☐ | ☐ | ☐ |
| Volleyball | ☐ | ☐ | ☐ | ☐ |
| Basketball | ☐ | ☐ | ☐ | ☐ |
| Little Athletics | ☐ | ☐ | ☐ | ☐ |
| Tennis | ☐ | ☐ | ☐ | ☐ |
| Cricket | ☐ | ☐ | ☐ | ☐ |
| Other | | | | |
| _____________ | ☐ | ☐ | ☐ | ☐ |
| _____________ | ☐ | ☐ | ☐ | ☐ |

2. **In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)?**

| | | |
|---|---|---|
| I don’t do PE | ☐ | |
| Hardly ever | ☐ | check |
| Sometimes | ☐ | only |
| Quite often | ☐ | one |
| Always | ☐ | |

3. **In the last 7 days what did you do most of the time at <u>RECESS?</u>**

| | | |
|---|---|---|
| Sat down (talking reading, doing school work) | ☐ | |
| Stood around or walked around | ☐ | check |
| Ran or played a little bit | ☐ | only |
| Ran around and played quite a bit | ☐ | one |
| Ran and played hard most of the time | ☐ | |

4. **In the last 7 days, what did you normally do <u>AT LUNCH</u> (besides eating lunch)?**

| | | |
|---|---|---|
| Sat down (talking reading, doing school work) | ☐ | |
| Stood around or walked around | ☐ | check |
| Ran or played a little bit | ☐ | only |
| Ran around and played quite a bit | ☐ | one |
| Ran and played hard most of the time | ☐ | |

5. **In the last 7 days, on how many days <u>RIGHT AFTER SCHOOL</u>, did you do sports, dance, or played games in which you were very active?**

| | | |
|---|---|---|
| None | ☐ | |
| 1 time last week | ☐ | check |
| 2 or 3 times last week | ☐ | only |
| 4 times last week | ☐ | one |
| 5 times last week | ☐ | |

6. **In the last 7 days, on how many <u>EVENINGS</u> did you do sports, dance, or played games in which you were very active?**

| | | |
|---|---|---|
| None | ☐ | |
| 1 time last week | ☐ | check |
| 2 or 3 times last week | ☐ | only |
| 4 times last week | ☐ | one |
| 5 times last week | ☐ | |

7. **<u>ON THE LAST WEEKEND</u>, how many times did you do sports, dance, or played games in which you were very active?**

| | | |
|---|---|---|
| None | ☐ | |
| 1 time last week | ☐ | check |
| 2 or 3 times last week | ☐ | only |
| 4 times last week | ☐ | one |
| 5 times last week | ☐ | |

**8. Which ONE of the following describes you best for the last 7 days? **Read ALL FIVE statements before deciding on the one answer that describes you****

A. All or most of my free time was spent doing things that involve little physical effort ☐

B. I sometimes (1-2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) ☐

C. I fairly often (3-4 times last week) did physical things in my free time ☐

D. I often (5-6 times last week) did physical things in my free time ☐

E. I very often (7 or more times last week) did physical things in my free time ☐

**9. Were you sick last week, or did anything prevent you from doing your normal physical activities?**

Yes ☐
No ☐

If Yes, what prevented you?_______________________________________________________________

**10. Mark how often you did physical activity (like playing sports, games, doing dance or any other physical activity) for each day last week.**

| | None | Little Bit | Medium | Often | Very Often |
|---|---|---|---|---|---|
| A. Monday | ☐ | ☐ | ☐ | ☐ | ☐ |
| B. Tuesday | ☐ | ☐ | ☐ | ☐ | ☐ |
| C. Wednesday | ☐ | ☐ | ☐ | ☐ | ☐ |
| D. Thursday | ☐ | ☐ | ☐ | ☐ | ☐ |
| E. Friday | ☐ | ☐ | ☐ | ☐ | ☐ |
| F. Saturday | ☐ | ☐ | ☐ | ☐ | ☐ |
| G. Sunday | ☐ | ☐ | ☐ | ☐ | ☐ |

## Appendix F: Instruction sheet for wearing the activity monitor

- The activity monitor has been placed on the belt which has been fitted firmly around the waist.
- The belt has been adjusted so that the activity monitor sits just above and in front of the right hip bone.
- Ensure that the belt is tight and will not move and that the monitor is securely fastened so that it will not move either.
- It is best to wear the belt under your jumper or shirt.
- Ensure that the marker on the monitor is facing the top and that the monitor is always in the same place on the belt.
- When you take it off, do not shake it. Just place it in a safe place ready for you to put it on again.
- Do not put it on top of a refrigerator or where it might get hot.
- You should only take it off just before you go to bed at night and put it on again when you are dressing in the morning.
- Do not wear it in the shower/bath or if you are going for a swim.
- If you are playing a game like netball and the umpire objects to you wearing the monitor during the game then it is OK to take it off for the game, but please remember to put it on again straight after the game.
- Remember that we would like you to wear the monitor everyday for the next 7 days, including the weekend. We will come to the school to collect the monitor next …………………………….. Please wear it everyday until then.
- If you have any problems or questions you can ring Liam Welsh on 0405 127060 or Dr Ric Roberts on 0414 282621.

**Name:** ________________________ **Monitor #** ________________________

**Date on** ________________________ **Date off** ________________________

# Appendix G: GXT DATA SHEET

Respiratory Laboratory, Department of Respiratory Medicine, Royal Children's Hospital, Melbourne

**Subject / UR number:**___________________________ _________
**Surname:**_____________________________________
**First Name:**___________________________________ _________
**Birth Date:**__________________________**Age:**_____ _________

**Height:** ___________________
**Weight:**___________
**BMI:**_______________________
**Sex M/F**

**Date:**______________**Test Nº:**___
**Time:**_____________
**Temperature:**______ _________
**Humidity:**_________

Diagnosis:_________________________________ _________
**Medication:**___________________________________ _________
**Time of Last Medication:**_______________________

**Predicted FEV1:**
**Actual Pre-Exercise FEV1:**
**% Predicted FEV1:**

**MVV** (35 x pred $FEV_1$):
**Target VE** (60%MVV):
Predicted Max HR:

| **Time (min)** | **Speed km/hr** | **Grade %** | **Predicted VE (%Target)** | **Actual VE** | **$SaO_2$** | **Pulse Rate** | **CERT Scale** |
|---|---|---|---|---|---|---|---|
| 0 Rest | 0 | 0 | 0%: | | | | |
| 1 | | | 60%: | | | | |
| 2 | | | 75%: | | | | |
| 3 | | | 90%: | | | | |
| 4 | | | 100%: | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |

Was the effort similar to the situations where the patient experiences breathlessness?

During exercise did the patient experience:
- ☐ Excessive breathlessness
- ☐ Wheeze
- ☐ Cough
- ☐ Chest tightness
- ☐ Nausea
- ☐ Headache
- ☐ Dizziness
- ☐ Stridor
- ☐ Pain

How were these sensations compared with the patient's usual exercise response?

| | | |
|---|---|---|
| **Peak HR __ __ __** | **% pred max HR __ __** | |
| **Peak RER: __ . __ __ (Range 1.0-1.2)** | | |
| **Resting SaO2 % __ __** | **End exercise SaO2 % __ __** | |
| **Peak fR (breaths/min) __ __** | **Peak $V_E$ (L): __ __** | **as a % of pred MVV: __ __** |
| **Peak $vO_2$ (ml/kg.min):** | **as a % of pred. peak $vO_2$: __ __** | |
| **AT (Vslope) (ml/kg.min): __ __.__** | **% Peak $vO_2$ _ _** | |
| **AT (GasExchange): __ __. __** | **% Peak $vO_2$ _ _** | |
| **Et$pCO_2$ (Kpa): __ . __ __** | **$O_2$ Equivalent __ __ . __** | **$CO_2$ Equivalent __ __ . __** |

# Appendix H: GXT Data and Graphical Output

Department of Respiratory Medicine, Respiratory Laboratory
Royal Children's Hospital, Melbourne, Australia

## Exercise Test Report

| | | | |
|---|---|---|---|
| Identification: | | | |
| Last Name: | | Height: | 140.9 cm |
| First Name: | | Weight: | 31.4 kg |
| Date of Birth: | 08/12/1992 | Sex: | male |
| Age: | 11 Years | Diagnosis: | |
| Protocol: | LE_NORM_IB-2 | Ergometer: | Treadmill |
| Test settings: | Open system | | |
| Date: | 05/07/2004 | Time: | 11:34:18 |
| Baro. pressure: | 760 mmHg | Temperature: | 23 °C |

Reason for Test:

Doctor:

Tester:

| Time min | V'E l/min | VO2/kg ml/min/kg | HR-ox bpm | RER | V'O2 ml/min | V'CO2 ml/min | PETO2 kPa | PETCO2 kPa | SpO2 % | BF 1/min | DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00:03 | 10 | 11.2 | - | 0.93 | 352 | 326 | 14.72 | 4.70 | 0 | 33 | 0.14 |
| 00:10 | 12 | 12.6 | - | 0.94 | 396 | 371 | 14.67 | 4.75 | 0 | 28 | 0.16 |
| 00:20 | 12 | 14.5 | - | 0.88 | 454 | 401 | 14.30 | 4.90 | 0 | 26 | 0.17 |
| 00:30 | 12 | 13.8 | - | 0.90 | 433 | 388 | 14.24 | 4.95 | 0 | 26 | 0.16 |
| 00:40 | 13 | 16.0 | - | 0.90 | 503 | 451 | 14.34 | 4.92 | 0 | 27 | 0.19 |
| 00:50 | 13 | 17.3 | - | 0.84 | 542 | 457 | 13.83 | 5.12 | 0 | 27 | 0.18 |
| 01:00 | 15 | 21.0 | - | 0.81 | 660 | 538 | 13.67 | 5.10 | 0 | 30 | 0.21 |
| 01:10 | 17 | 22.4 | - | 0.85 | 703 | 600 | 14.03 | 4.99 | 0 | 31 | 0.24 |
| 01:20 | 17 | 23.9 | - | 0.84 | 750 | 632 | 13.84 | 5.12 | 0 | 30 | 0.24 |
| 01:30 | 18 | 24.4 | - | 0.86 | 766 | 659 | 13.74 | 5.21 | 0 | 24 | 0.25 |
| 01:40 | 21 | 27.8 | - | 0.87 | 873 | 763 | 13.95 | 5.12 | 0 | 30 | 0.29 |
| 01:50 | 20 | 25.9 | - | 0.90 | 814 | 730 | 13.76 | 5.30 | 0 | 27 | 0.28 |
| 02:00 | 21 | 26.9 | - | 0.92 | 845 | 773 | 14.12 | 5.13 | 0 | 29 | 0.29 |
| 02:10 | 22 | 28.7 | - | 0.90 | 902 | 811 | 14.01 | 5.21 | 0 | 31 | 0.31 |
| 02:20 | 24 | 30.1 | - | 0.92 | 945 | 870 | 14.17 | 5.16 | 0 | 31 | 0.33 |
| 02:30 | 24 | 30.2 | - | 0.94 | 948 | 888 | 14.32 | 5.12 | 0 | 32 | 0.34 |
| 02:40 | 26 | 31.2 | - | 0.96 | 980 | 940 | 14.30 | 5.16 | 0 | 32 | 0.36 |
| 02:50 | 26 | 32.7 | - | 0.94 | 1028 | 971 | 14.29 | 5.17 | 0 | 34 | 0.37 |
| 03:00 | 27 | 33.0 | - | 0.98 | 1036 | 1012 | 14.34 | 5.18 | 0 | 32 | 0.38 |
| 03:10 | 24 | 33.3 | - | 0.91 | 1045 | 948 | 13.57 | 5.52 | 0 | 24 | 0.34 |
| 03:20 | 28 | 34.2 | - | 0.96 | 1075 | 1028 | 14.33 | 5.18 | 0 | 33 | 0.39 |
| 03:30 | 27 | 31.5 | - | 1.01 | 988 | 996 | 14.50 | 5.17 | 0 | 36 | 0.37 |
| 03:40 | 29 | 36.1 | - | 0.95 | 1134 | 1080 | 14.37 | 5.16 | 0 | 37 | 0.40 |
| 03:50 | 31 | 35.8 | - | 1.01 | 1125 | 1134 | 14.61 | 5.15 | 0 | 37 | 0.43 |
| 04:00 | 31 | 36.7 | - | 1.01 | 1153 | 1170 | 14.50 | 5.22 | 0 | 35 | 0.43 |
| 04:10 | 34 | 39.7 | - | 1.03 | 1246 | 1284 | 14.66 | 5.16 | 0 | 37 | 0.48 |
| 04:20 | 35 | 38.9 | - | 1.05 | 1221 | 1286 | 14.83 | 5.08 | 0 | 34 | 0.49 |
| 04:30 | 36 | 43.7 | - | 1.00 | 1374 | 1380 | 14.52 | 5.18 | 0 | 37 | 0.51 |
| 04:40 | 38 | 42.1 | - | 1.08 | 1323 | 1428 | 14.80 | 5.15 | 0 | 35 | 0.53 |
| 04:50 | 38 | 41.7 | - | 1.09 | 1309 | 1429 | 14.93 | 5.10 | 0 | 39 | 0.53 |
| 05:00 | 37 | 41.4 | - | 1.07 | 1301 | 1392 | 14.82 | 5.15 | 0 | 33 | 0.52 |
| 05:10 | 40 | 43.5 | - | 1.06 | 1366 | 1454 | 14.86 | 5.08 | 0 | 37 | 0.55 |
| 05:20 | 42 | 44.5 | - | 1.09 | 1399 | 1522 | 14.97 | 5.01 | 0 | 40 | 0.59 |
| 05:30 | 46 | 43.8 | - | 1.12 | 1376 | 1540 | 15.35 | 4.77 | 0 | 43 | 0.64 |
| 05:40 | 47 | 45.2 | - | 1.10 | 1420 | 1569 | 15.28 | 4.80 | 0 | 43 | 0.65 |
| 05:50 | 47 | 45.1 | - | 1.11 | 1416 | 1575 | 15.26 | 4.80 | 0 | 43 | 0.65 |
| 06:00 | 47 | 45.7 | - | 1.10 | 1434 | 1581 | 15.29 | 4.78 | 0 | 42 | 0.66 |
| 06:10 | 46 | 47.4 | - | 1.05 | 1489 | 1558 | 15.06 | 4.86 | 0 | 43 | 0.64 |
| 06:20 | 45 | 45.9 | - | 1.07 | 1441 | 1540 | 15.18 | 4.79 | 0 | 42 | 0.63 |
| 06:30 | 47 | 46.8 | - | 1.06 | 1469 | 1552 | 15.21 | 4.78 | 0 | 44 | 0.65 |
| 06:40 | 49 | 47.3 | - | 1.11 | 1485 | 1646 | 15.25 | 4.75 | 0 | 43 | 0.68 |
| 06:50 | 45 | 46.0 | - | 1.07 | 1446 | 1549 | 15.08 | 4.85 | 0 | 40 | 0.62 |

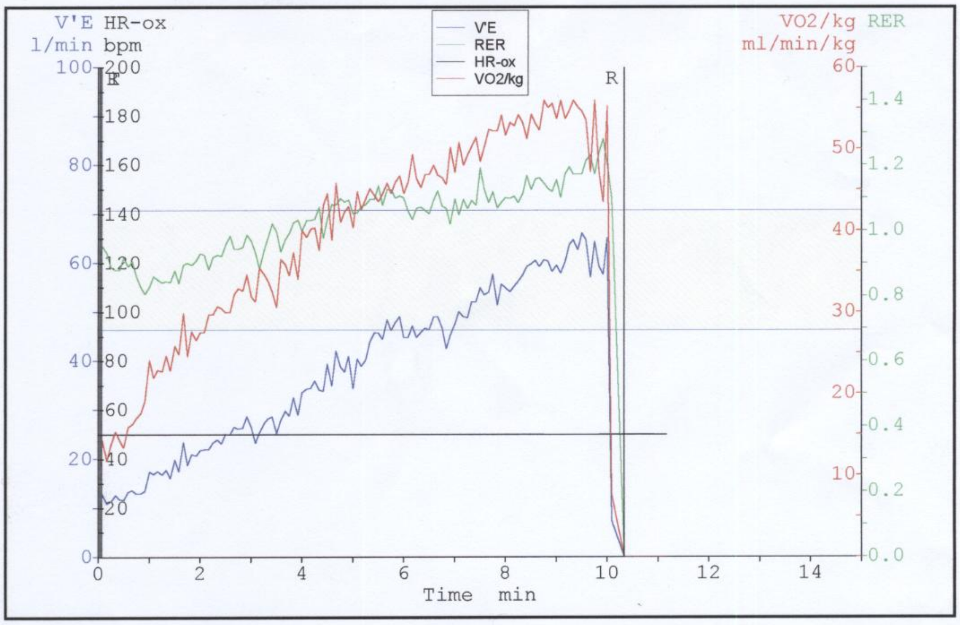
CFEXCHILD 10/05/2006 12:32 1/3

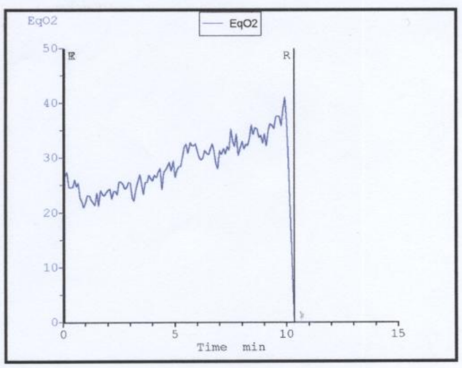
| Time min | V'E l/min | VO2/kg ml/min/kg | HR-ox bpm | RER | V'O2 ml/min | V'CO2 ml/min | PETO2 kPa | PETCO2 kPa | SpO2 % | BF l/min | DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 06:50 | 45 | 46.2 | - | 1.07 | 1446 | 1549 | 15.08 | 4.85 | 0 | 40 | 0.62 |
| 07:00 | 46 | 48.7 | - | 1.05 | 1529 | 1612 | 15.06 | 4.85 | 0 | 39 | 0.65 |
| 07:10 | 50 | 49.4 | - | 1.07 | 1550 | 1658 | 15.23 | 4.74 | 0 | 45 | 0.69 |
| 07:20 | 51 | 49.8 | - | 1.08 | 1564 | 1693 | 15.22 | 4.74 | 0 | 45 | 0.71 |
| 07:30 | 53 | 50.1 | - | 1.12 | 1573 | 1769 | 15.37 | 4.66 | 0 | 44 | 0.74 |
| 07:40 | 54 | 51.3 | - | 1.10 | 1612 | 1781 | 15.35 | 4.69 | 0 | 44 | 0.75 |
| 07:50 | 55 | 52.2 | - | 1.10 | 1640 | 1798 | 15.37 | 4.70 | 0 | 45 | 0.77 |
| 08:00 | 55 | 52.9 | - | 1.09 | 1661 | 1816 | 15.41 | 4.66 | 0 | 47 | 0.77 |
| 08:10 | 55 | 53.1 | - | 1.10 | 1666 | 1833 | 15.29 | 4.79 | 0 | 44 | 0.76 |
| 08:20 | 57 | 53.7 | - | 1.10 | 1686 | 1852 | 15.43 | 4.69 | 0 | 45 | 0.79 |
| 08:30 | 59 | 52.5 | - | 1.15 | 1648 | 1893 | 15.61 | 4.60 | 0 | 45 | 0.83 |
| 08:40 | 60 | 52.7 | - | 1.16 | 1655 | 1917 | 15.69 | 4.54 | 0 | 45 | 0.84 |
| 08:50 | 61 | 55.5 | - | 1.14 | 1743 | 1979 | 15.63 | 4.59 | 0 | 46 | 0.84 |
| 09:00 | 59 | 54.5 | - | 1.14 | 1712 | 1949 | 15.56 | 4.63 | 0 | 47 | 0.82 |
| 09:10 | 59 | 54.8 | - | 1.14 | 1722 | 1955 | 15.53 | 4.64 | 0 | 46 | 0.82 |
| 09:20 | 64 | 55.3 | - | 1.18 | 1738 | 2054 | 15.81 | 4.49 | 0 | 48 | 0.90 |
| 09:30 | 64 | 54.8 | - | 1.17 | 1722 | 2019 | 15.86 | 4.44 | 0 | 51 | 0.90 |
| 09:40 | 61 | 50.3 | - | 1.22 | 1579 | 1929 | 15.81 | 4.49 | 0 | 47 | 0.85 |
| 09:50 | 62 | 51.6 | - | 1.20 | 1619 | 1947 | 15.79 | 4.48 | 0 | 50 | 0.86 |
| 10:00 | 61 | 48.7 | - | 1.24 | 1528 | 1898 | 15.92 | 4.43 | 0 | 51 | 0.85 |
| 10:10 | 7 | 7.7 | - | 1.10 | 241 | 265 | 15.35 | 4.85 | 0 | 12 | 0.10 |
| 10:20 | 0 | 0.0 | - | 0.00 | 0 | 0 | 19.40 | 0.49 | 0 | 4 | 0.00 |
| 11:00 | 0 | 0.0 | - | 0.00 | 0 | 0 | 19.40 | 0.49 | 0 | 4 | 0.00 |
| 11:10 | 0 | 0.0 | - | 0.00 | 0 | 0 | 19.40 | 0.49 | 0 | 4 | 0.00 |

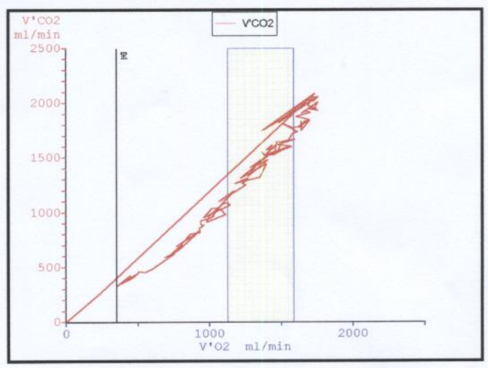
00:02 **Reference**
00:04 **Test:**
10:20 **Recovery**

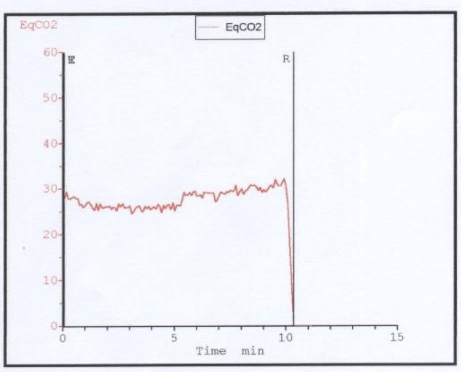
**Intrabreath**

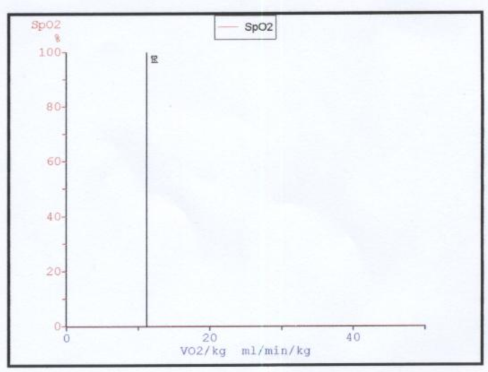
| Time | VTex | BF | t-in | VTin | t-ex | FETCO2 | FETO2 | EELV |
|---|---|---|---|---|---|---|---|---|
| 01:37 | 0.823 | 29.4 | 0.88 | 0.824 | 1.16 | 5.20 | 15.07 | 2.40 |
| 04:11 | 1.157 | 30.0 | 1.00 | 1.187 | 1.00 | 5.35 | 15.51 | 2.06 |
| 05:53 | 1.230 | 41.7 | 0.68 | 1.102 | 0.76 | 5.01 | 16.11 | 2.16 |
| 08:02 | 1.427 | 34.1 | 1.00 | 1.576 | 0.76 | 5.12 | 15.97 | 1.65 |
| 09:37 | 1.415 | 41.7 | 0.72 | 1.368 | 0.72 | 4.88 | 16.43 | 1.80 |

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# Appendix I: Human Research Ethics Approval

ACU National

University Human Research Ethics Committee

Ethics Clearance for a Research Project – Renewal of Approval Form

| | |
|---|---|
| **Principal Investigator/s (if staff):** Mr Justin Kemp; Dr RGD Roberts | **Campus:** Melbourne |
| **Co Investigator:** | **Campus:** |
| **Name of Researcher(s) [if student(s)]:** Mr Liam Welsh | **Campus:** Melbourne |

**Ethics clearance has been renewed for the following project:**

*Physical activity, aerobic fitness and fatness of children*

**for the period:** 31.7.02-30.3.03

**Human Research Ethics Committee Register Number:** V2001.02-11

**subject to the following conditions as stipulated in the National Health and Medical Research Council (NHMRC) Statement on Human Experimentation and Supplementary Notes 1992:**

(i) that principal investigators provide reports annually on the form supplied by the Institutional Ethics Committee, on matters including:
- security of records;
- compliance with approved consent procedures and documentation;
- compliance with special conditions, and

(ii) as a condition of approval of the research protocol, require that investigators report immediately anything which might affect ethical acceptance of the protocol, including:
- adverse effects on participants;
- proposed changes in the protocol, and/or
- unforeseen events that might affect continued ethical acceptability of the project.

**and subject to clarification of the following to the University Human Research Ethics Committee:**

*A Final Report Form will need to be completed and submitted to the HREC within one month of completion of the project.*
*OR*
*An Annual Progress Report Form will need to be completed and submitted to the HREC within one month of the anniversary date of approval.*

**Please sign, date and return this form (with any additional information, or supporting documents to show completion of any amendments requested) to your local Research Services Officer to whom you submitted your application. This is essential before final approval by the University Human Research Ethics Committee is confirmed.**

**Signed:** K. M. Ryan **Date:** 22-8-02

**Research Services Officer**

# Appendix J: Chapter 1 Appendices

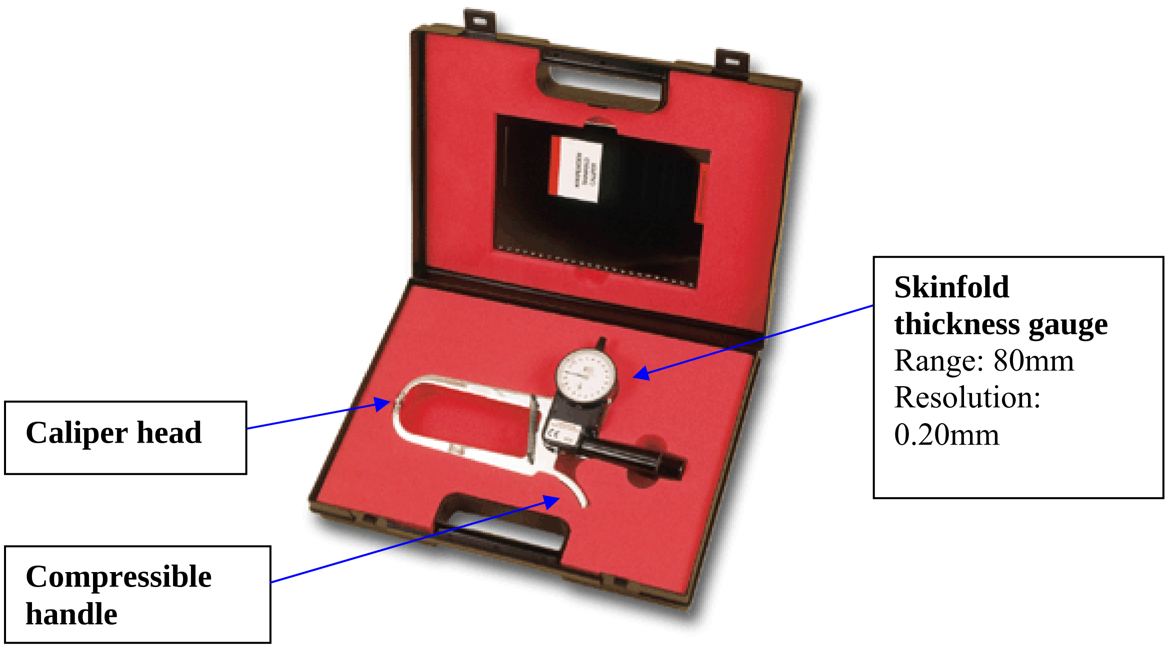
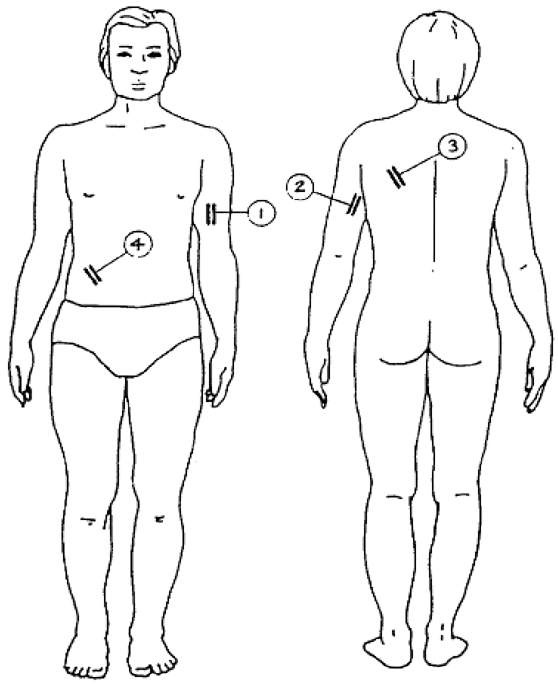



**Figure 1.1 Harpenden skinfold calipers**

This device is used to measure subcutaneous adipose tissue thickness at selected body sites for the estimation of body fat. By straining the compressible handle, the caliper head opens to grasp the desired skinfold. Measurements can then be observed on the skinfold thickness gauge.

Source: (www.assist.co.uk/harpenden/index.htm)




1) **Biceps** - The anterior surface of the biceps midway between the anterior auxiliary fold and the antecubital fossa.
2) **Triceps** - A vertical fold on the posterior midline of the upper arm, over the triceps muscle, halfway between the acromion process (bony process on top of the shoulder) and olecranon process (bony process on elbow). The elbow should be extended and the arm relaxed.
3) **Subscapular** - The fold is taken on the diagonal line coming from the vertebral border to between 1 and 2 cm from the inferior angle of the scapulae. (A diagonal fold about 1 to 2 cm below the point of the shoulder blade and 1 - 2 cm toward the arm).
4) **Suprailiac** - A diagonal fold above the crest of the ilium at the spot where an imaginary line would come down from the anterior auxiliary line just above the hip bone and 2 - 3 cm forward.

**Figure 1.2 Four common skinfold sites for male and female subjects: bicep, tricep, subscapular, suprailiac**

Note the above descriptions for the correct location and measurement of each skinfold site.

Source: (www.assist.co.uk/harpenden/index.htm)

| | BMI: 25 ($kg/m^2$) | | BMI: 30 ($kg/m^2$) | |
|---|---|---|---|---|
| Age (years) | Boys | Girls | Boys | Girls |
| 9 | 19.1 | 19.1 | 22.8 | 22.8 |
| 9.5 | 19.5 | 19.5 | 23.4 | 23.5 |
| 10 | 19.8 | 19.9 | 24.0 | 24.1 |
| 10.5 | 20.2 | 20.3 | 24.6 | 24.8 |
| 11 | 20.6 | 20.7 | 25.1 | 25.4 |
| 11.5 | 20.9 | 21.2 | 25.6 | 26.1 |
| 12 | 21.2 | 21.7 | 26.0 | 26.7 |
| 12.5 | 21.6 | 22.1 | 26.4 | 27.2 |
| 13 | 21.9 | 22.6 | 26.8 | 27.8 |
| 13.5 | 22.3 | 23.0 | 27.2 | 28.2 |
| 14 | 22.6 | 23.3 | 27.6 | 28.6 |
| 14.5 | 23.0 | 23.7 | 28.0 | 28.9 |
| 15 | 23.3 | 23.9 | 28.3 | 29.1 |

**Figure 1.3 International BMI cut-off points for overweight and obesity in children and adolescents aged 9 to 15 years. The cut-off points listed are categorised by gender and defined to pass through BMI levels of 25 $kg/m^2$ and 30 $kg/m^2$ at age 18 years** (Cole *et al.*, 2000)

| | BMI: 25 ($kg/m^2$) [3] | | BMI: 30 ($kg/m^2$) [4] | |
|---|---|---|---|---|
| Age (years)[2] | Boys | Girls | Boys | Girls |
| 9 | 20 (19,21) | 26 (25,27) | 33 (31,36) | 37 (36,39) |
| 10 | 21 (20,22) | 28 (27,29) | 35 (32,37) | 41 (39,43) |
| 11 | 22 (21,23) | 30 (29,31) | 36 (33,38) | 43 (42,46) |
| 12 | 22 (21,23) | 32 (31,33) | 35 (33,38) | 46 (44,48) |
| 13 | 23 (21,23) | 33 (32,34) | 35 (32,37) | 46 (45,49) |
| 14 | 23 (21,23) | 34 (33,35) | 34 (31,36) | 46 (45,49) |
| 15 | 22 (21,23) | 34 (33,35) | 32 (29,34) | 46 (44,49) |

[1]Mean (95% Confidence Intervals)
[2]Calculated for each half year of age
[3]The BMI at each age that is equivalent to a BMI of 25 in an 18 year old as calculated according to Cole *et al*. (2000)
[4]The BMI at each age that is equivalent to a BMI of 30 in an 18 year old as calculated according to Cole *et al*. (2000)

**Figure 1.4 Predicted percentage body fat at BMI ($kg/m^2$) cut-off points according to age and gender[1]** (Taylor *et al*., 2002)

# Appendix K: Chapter 2 Appendices


**Figure 2.1 Biodynamics model 310e analyser (Biodynamics Corporation, Seattle, Washington)**

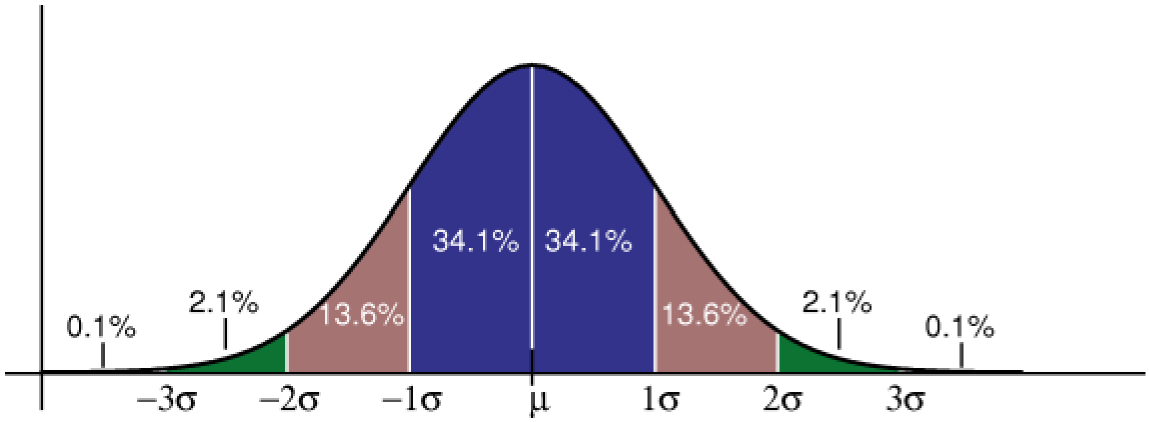
The Biodynamics model 310e analyser is a portable, battery-powered bioelectrical impedance analyser. Assessments are conducted using a connection between the analyser and the wrist and ankle of the subject. Connections are made through standard electrocardiogram sensor pad electrodes. Resistance and reactance, the two components of impedance, are measured directly from the body. Using regression analysis, the analyser computes percentage body fat.

Source: www.biodyncorp.com

Kolmogorov-Smirnov Test

The one-sample Kolmogorov-Smirnov test procedure compares the observed cumulative distribution function for a variable with a specified theoretical distribution, which may be normal, uniform, Poisson, or exponential. A cumulative distribution function returns the probability that a variate of a given distribution falls below a given value for continuous functions and at or below a given value for discrete functions. A 'normal' distribution is defined by its location (mean) and scale (standard deviation) parameters. Its density function has a bell shape which is symmetric about its mean. Around 68% of the values of a normal variate will fall within one standard deviation of the mean, 95% within two standard deviations, and 99.7% within three standard deviations. A graphical representation of a normal distribution can be seen in Figure 2.5. Unlike much statistical testing, a significant result for a Kolmogorov-Smirnov test (i.e. Z statistic $<0.05$) is generally an unwelcome result as it indicates that a distribution is detached from normal.

In the case where a variate was found not to display a normal distribution, a log transformation was undertaken with a subsequent Kolmogorov-Smirnov test performed to determine the variate's normality.




μ = mean
σ = standard deviation (Banerjee, 2003)

**Figure 2.6 Standard normal (Gaussian) distribution histogram**

A normal distribution has a mean of zero and a standard deviation of one. If a dataset follows a normal distribution, then about 68% of the observations will fall within one standard deviation of the mean, 95% within two standard deviations of the mean, and 99.7% within three standard deviations of the mean.

# Appendix L: Chapter 3 Appendices

## Table 3.2 Kolmogorov-Smirnov test results

| Variable | N | Kolmogorov-Smirnov Z | Significance |
|---|---|---|---|
| **Age (years)** | 635 | 0.583 | 0.885 |
| **Height (cm)** | 635 | 0.473 | 0.979 |
| **Mass (kg)** | 635 | 1.303 | 0.070 |
| **FM (kg)** | 635 | 1.521 | 0.200 |
| **FFM (kg)** | 635 | 1.708 | 0.213 |
| **HR (bpm)** | 635 | 0.588 | 0.807 |
| **BMI ($kg/m^2$)** | 635 | 2.504 | 0.000 |
| **Log BMI ($kg/m^2$)** | 635 | 1.806 | 0.267 |
| **%BF** | 635 | 1.329 | 0.100 |
| **6MRD (m)** | 635 | 1.058 | 0.213 |
| **6MRD/FFM (m/kgFFM)** | 635 | 0.800 | 0.540 |
| **Predicted Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 635 | 0.939 | 0.341 |
| **PAQ-C (index)** | 635 | 0.820 | 0.517 |
| **Activity monitor counts (counts/day)** | 26 | 1.053 | 0.218 |
| **$FEV_1$ (% Predicted)** | 635 | 1.494 | 0.116 |

## Table 3.9 Regression analysis for aerobic fitness and BMI

| Group | Variable | Regression Equation | $R^2$ | p |
|---|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | -25.1 (BMI) + 1572.3 | 0.21 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -1.90 (BMI) + 71.70 | 0.53 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.83 (BMI) + 62.80 | 0.21 | 0.0001 |
| **Grade 5 Females** | **6MRD** (m) | -22.4 (BMI) + 1412.6 | 0.14 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -2.16 (BMI) + 76.0 | 0.51 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.74 (BMI) + 59.00 | 0.14 | 0.0001 |
| **Grade 8 Males** | **6MRD** (m) | -25.5 (BMI) + 1714.0 | 0.22 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -1.45 (BMI) + 58.50 | 0.52 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.85 (BMI) + 64.4 | 0.22 | 0.0001 |
| **Grade 8 Females** | **6MRD** (m) | -14.4 (BMI) + 1307.7 | 0.14 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -1.13 (BMI) + 50.82 | 0.51 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.48 (BMI) + 51.9 | 0.14 | 0.0001 |

**Table 3.12 Regression analysis for aerobic fitness and %BF**

| Group | Variable | Regression Equation | $R^2$ | p |
|---|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | -15.6 (%BF) + 1446.1 | 0.26 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -1.0 (%BF) + 57.7 | 0.43 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.52 (%BF) + 58.60 | 0.26 | 0.0001 |
| **Grade 5 Females** | **6MRD** (m) | -15.3 (%BF) + 1428.8 | 0.19 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -1.0 (%BF) + 64.0 | 0.31 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.51 (%BF) + 59.10 | 0.19 | 0.0001 |
| **Grade 8 Males** | **6MRD** (m) | -18.9 (%BF) + 1607.2 | 0.33 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -0.6 (%BF) + 42.7 | 0.27 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.63 (%BF) + 60.80 | 0.33 | 0.0001 |
| **Grade 8 Females** | **6MRD** (m) | -15.3 (%BF) + 1466.3 | 0.20 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -0.9 (%BF) + 55.5 | 0.44 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.51 (%BF) + 57.20 | 0.20 | 0.0001 |

# Appendix M: Chapter 4 Appendices

## Table 4.2 Kolmogorov-Smirnov test results

| Variable | N | Kolmogorov-Smirnov Z | Significance |
|---|---|---|---|
| **Age (years)** | 125 | 0.682 | 0.741 |
| **Height (cm)** | 125 | 0.853 | 0.461 |
| **Mass (kg)** | 125 | 0.853 | 0.460 |
| **FM (kg)** | 125 | 0.963 | 0.311 |
| **FFM (kg)** | 125 | 1.058 | 0.213 |
| **Heart rate (bpm)** | 125 | 0.770 | 0.588 |
| **BMI ($kg/m^2$)** | 125 | 1.141 | 0.148 |
| **%BF** | 125 | 0.955 | 0.322 |
| **6MRD (m)** | 125 | 0.783 | 0.571 |
| **6MRD/FFM (m/kgFFM)** | 125 | 0.652 | 0.788 |
| **Predicted Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 125 | 1.177 | 0.125 |
| **PAQ-C** | 125 | 0.640 | 0.808 |
| **Activity monitor counts (counts/day)** | 29 | 1.095 | 0.182 |
| **$FEV_1$ (% predicted)** | 125 | 1.334 | 0.060 |
| **ASQ** | 125 | 1.200 | 0.112 |

**Table 4.4 Spirometric comparative analyses – Chapter 3 non-asthmatic versus Chapter 4 asthmatic values (data shown are p values for unpaired *t* tests)**

| | Grade 5 Males | Grade 5 Females | Grade 8 Males | Grade 8 Females |
|---|---|---|---|---|
| **$FEV_1$ (l)** | 0.10 | 0.90 | 0.89 | 0.25 |
| **$FEV_1$ (% Predicted)** | 0.16 | 0.32 | 0.47 | 0.10 |
| **FVC (l)** | 0.39 | 0.77 | 0.63 | 0.65 |
| **FVC (% Predicted)** | 0.47 | 0.48 | 0.30 | 0.65 |
| **FER ($FEV_1$/FVC)** | 0.17 | 0.61 | 0.23 | 0.24 |

**Table 4.8 Body composition comparative analyses – Chapter 3 non-asthmatic versus Chapter 4 asthmatic values (data shown are p values for unpaired *t* tests)**

| | Grade 5 Males | Grade 5 Females | Grade 8 Males | Grade 8 Females |
|---|---|---|---|---|
| **BMI** | 0.89 | 0.18 | 0.19 | 0.64 |
| **%BF** | 0.73 | 0.30 | 0.57 | 0.47 |

**Table 4.10 Aerobic fitness comparative analyses – Chapter 3 non-asthmatic versus Chapter 4 asthmatic values (data shown are p values for unpaired *t* tests)**

| | Grade 5 Males | Grade 5 Females | Grade 8 Males | Grade 8 Females |
|---|---|---|---|---|
| **6MRD** | 0.87 | 0.10 | 0.33 | 0.56 |
| **6MRD/FFM** | 0.96 | 0.18 | 0.50 | 0.36 |

**Table 4.12 Amount of time and proportion of time spent in daily physical activity classified by intensity range**

| | **Grade 5 Male** (n=6) | **Grade 5 Female** (n=9) | **Grade 8 Male** (n=6) | **Grade 8 Female** (n=8) |
|---|---|---|---|---|
| **Light (mins/day)** | 431.3 ± 156.6 | 435.0 ± 75.5 | 467.9 ± 115.0 | 450.3 ± 80.5 |
| **Time %** | 44.9 | 45.3 | 48.7 | 46.9 |
| **Moderate (mins/day)** | 422.4 ± 127.3 | 431.1 ± 101.0 | 402.6 ± 83.6 | 434.5 ± 53.3 |
| **Time %** | 44.0 | 44.9 | 41.9 | 45.3 |
| **Vigorous (mins/day)** | 83.3 ± 37.1 | 80.8 ± 17.5 | 78.7 ± 37.0 | 61.1 ± 31.6 |
| **Time %** | 8.7 | 8.4 | 8.2 | 6.4 |
| **Extreme (mins/day)** | 19.70 ± 17.7 | 13.1 ± 12.6 | 11.3 ± 10.3 | 14.2 ± 18.1 |
| **Time %** | 2.4 | 1.4 | 1.2 | 1.4 |

Mean ± SD

**Table 4.13 Physical activity comparative analyses – Chapter 3 non-asthmatic versus Chapter 4 asthmatic values (data shown are p values for Student's unpaired *t* tests)**

| | Grade 5 Males | Grade 5 Females | Grade 8 Males | Grade 8 Females |
|---|---|---|---|---|
| **PAQ-C** | 0.57 | 0.01 | 0.63 | 0.53 |
| **Activity monitor counts** | 0.38 | 0.86 | 0.59 | 0.51 |
| **MET** | 0.37 | 0.95 | 0.60 | 0.39 |

Predicted peak $\dot{V}O_2$ is not listed as it is derived from 6MRD and hence the p values are the same.

**Table 4.14 BMI and %BF as categorised by Rosier *et al*. (1994) asthma severity scale**

| Group | Variable | Trivial | Mild | Moderate/Severe |
|---|---|---|---|---|
| **Grade 5 Males** | **BMI** | 18.9 ± 4.1 | 19.0 ± 3.2 | 18.1 ± 3.6 |
| | **%BF** | 21.1 ± 7.7 | 23.1 ± 6.2 | 22.4 ± 8.7 |
| | | (n = 14) | (n = 16) | (n = 12) |
| **Grade 5 Females** | **BMI** | 18.1 ± 2.4 | 19.2 ± 3.5 | 20.1 ± 3.4 |
| | **%BF** | 27.9 ± 4.0 | 29.1 ± 5.1 | 29.3 ± 5.6 |
| | | (n = 7) | (n = 9) | (n = 5) |
| **Grade 8 Males** | **BMI** | 21.8 ± 4.0 | 20.7 ± 3.4 | 21.0 ± 4.7 |
| | **%BF** | 24.3 ± 7.1 | 19.5 ± 5.7 | 21.6 ± 5.7 |
| | | (n = 15) | (n = 8) | (n = 9) |
| **Grade 8 Females** | **BMI** | 20.6 ± 3.8 | 22.2 ± 3.4 | 22.3 ± 2.8 |
| | **%BF** | 29.6 ± 4.5 | 30.1 ± 4.4 | 32.6 ± 3.8 |
| | | (n = 9) | (n = 6) | (n = 15) |

Mean ± SD

**Table 4.15 Regression analysis for body composition and asthma severity (ASQ)**

| Group | ASQ = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males (n=42)** | -0.14 (BMI) + 9.30<br>0.11 (%BF) + 4.15 | 0.01<br>0.03 | 0.52<br>0.28 |
| **Grade 5 Females (n=21)** | 0.32 (BMI) + 0.89<br>0.08 (%BF) + 4.54 | 0.06<br>0.01 | 0.28<br>0.67 |
| **Grade 8 Males (n=32)** | 0.004 (BMI) + 5.70<br>-0.09 (%BF) + 7.70 | 0.00<br>0.02 | 0.98<br>0.48 |
| **Grade 8 Females (n=30)** | 0.45 (BMI) – 0.54<br>0.52 (%BF) – 7.62 | 0.05<br>0.13 | 0.25<br>0.10 |

**Table 4.16 6MRD, 6MRD/FFM and predicted peak $\dot{V}O_2$ as categorised by Rosier *et al.* (1994) asthma severity scale**

| Group | Variable | Trivial | Mild | Moderate/Severe |
|---|---|---|---|---|
| **Grade 5 Males** | **6MRD** (m) | 1109.3 ± 134.5 | 1090.3 ± 133.8 | 1106.6 ± 151.0 |
| | **6MRD/FFM** (m/kgFFM) | 35.4 ± 8.0 | 35.6 ± 6.8 | 39.8 ± 12.5 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | 47.4 ± 4.7 | 46.8 ± 4.4 | 47.3 ± 5.0 |
| | | (n = 14) | (n = 16) | (n = 12) |
| **Grade 5 Females** | **6MRD** (m) | 888.6 ± 199.0 | 964.4 ± 119.9 | 950.0 ± 162.0 |
| | **6MRD/FFM** (m/kgFFM) | 35.9 ± 9.3 | 34.0 ± 8.2 | 31.7 ± 8.1 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | 41.2 ± 6.6 | 43.7 ± 4.0 | 43.2 ± 5.4 |
| | | (n = 7) | (n = 9) | (n = 5) |
| **Grade 8 Males** | **6MRD** (m) | 1159.3 ± 260.1 | 1171.3 ± 191.3 | 1142.2 ± 186.0 |
| | **6MRD/FFM** (m/kgFFM) | 28.7 ± 8.6 | 26.9 ± 6.2 | 27.9 ± 10.8 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | 45.9 ± 8.6 | 46.3 ± 6.4 | 45.4 ± 6.2 |
| | | (n = 15) | (n = 8) | (n = 9) |
| **Grade 8 Females** | **6MRD** (m) | 1027.2 ± 147.6 | 988.0 ± 95.2 | 1021.0 ± 170.3 |
| | **6MRD/FFM** (m/kgFFM) | 27.7 ± 6.5 | 24.9 ± 4.1 | 24.5 ± 6.7 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | 42.6 ± 4.9 | 41.3 ± 3.2 | 42.4 ± 5.7 |
| | | (n = 9) | (n = 6) | (n = 15) |

Mean ± SD

**Table 4.17 Regression analysis for aerobic fitness and asthma severity (ASQ)**

| Group | ASQ = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males (n=42)** | 0.003 (6MRD) + 3.89 | 0.006 | 0.64 |
| | 0.17 (6MRD/FFM) + 0.46 | 0.10 | 0.04 |
| | 0.08 (Peak $\dot{V}O_2$) + 3.04 | 0.006 | 0.64 |
| **Grade 5 Females (n=21)** | 0.002 (6MRD) + 4.65 | 0.009 | 0.68 |
| | -0.12 (6MRD/FFM) + 11.14 | 0.07 | 0.26 |
| | 0.07 (Peak $\dot{V}O_2$) + 3.80 | 0.009 | 0.68 |
| **Grade 8 Males (n=32)** | -0.002 (6MRD) + 7.80 | 0.007 | 0.63 |
| | -0.07 (6MRD/FFM) + 7.74 | 0.02 | 0.46 |
| | -0.05 (Peak $\dot{V}O_2$) + 8.20 | 0.007 | 0.63 |
| **Grade 8 Females (n=30)** | -0.008 (6MRD) + 17.03 | 0.03 | 0.34 |
| | -0.26 (6MRD/FFM) 15.90 | 0.07 | 0.18 |
| | -0.23 (Peak $\dot{V}O_2$) + 19.02 | 0.03 | 0.34 |

**Table 4.18 PAQ-C as categorised by Rosier *et al*. (1994) asthma severity scale**

| Group | Variable | Trivial | Mild | Moderate/Severe |
|---|---|---|---|---|
| **Grade 5 Males** | **PAQ-C** | 3.23 ± 0.70 (n = 14) | 3.53 ± 0.60 (n = 16) | 3.20 ± 0.53 (n = 12) |
| **Grade 5 Females** | **PAQ-C** | 2.62 ± 0.50 (n = 7) | 2.75 ± 0.43 (n = 9) | 2.65 ± 0.40 (n = 5) |
| **Grade 8 Males** | **PAQ-C** | 3.00 ± 0.70 (n = 15) | 3.11 ± 0.70 (n = 8) | 3.00 ± 0.61 (n = 9) |
| **Grade 8 Females** | **PAQ-C** | 2.72 ± 0.70 (n = 9) | 1.92 ± 0.56 (n = 6) | 2.40 ± 0.54 (n = 15) |

Mean ± SD

**Table 4.19 Correlation analysis for activity monitor counts and estimated MET versus asthma severity (ASQ)**

| Group | Variable | Pearson's r | p |
|---|---|---|---|
| **Grade 5 Males (n=6)** | **Activity Monitor Counts** | 0.05 | 0.92 |
| | **MET** | -0.02 | 0.97 |
| **Grade 5 Females (n=9)** | **Activity Monitor Counts** | 0.56 | 0.11 |
| | **MET** | 0.51 | 0.16 |
| **Grade 8 Males (n=6)** | **Activity Monitor Counts** | 0.20 | 0.70 |
| | **MET** | 0.22 | 0.68 |
| **Grade 8 Females (n=8)** | **Activity Monitor Counts** | -0.64 | 0.09 |
| | **MET** | -0.56 | 0.15 |

**Table 4.20 Regression analysis for physical activity and asthma severity (ASQ)**

| Group | ASQ = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males** | 0.92 (PAQ-C) + 3.72 | 0.01 | 0.46 |
| | 0.002 (Activity Monitor Counts) + 7.00 | 0.003 | 0.92 |
| | -0.74 (MET) + 9.50 | 0.0005 | 0.97 |
| **Grade 5 Females** | -0.56 (PAQ-C) + 8.44 | 0.004 | 0.80 |
| | 0.01 (Activity Monitor Counts) + 2.06 | 0.32 | 0.11 |
| | 10.84 (MET) – 16.70 | 0.26 | 0.16 |
| **Grade 8 Males** | 0.48 (PAQ-C) + 4.30 | 0.005 | 0.71 |
| | 0.003 (Activity Monitor Counts) + 2.61 | 0.04 | 0.69 |
| | 2.92 (MET) – 1.97 | 0.05 | 0.68 |
| **Grade 8 Females** | -1.57 (PAQ-C) + 12.90 | 0.03 | 0.40 |
| | -0.01 (Activity Monitor Counts) + 14.31 | 0.40 | 0.09 |
| | -12.20 (MET) + 32.03 | 0.31 | 0.15 |

## Table 4.21 Activity monitor counts versus PAQ-C

| | Grade 5 Male (n=6) | Grade 5 Female (n=9) | Grade 8 Male (n=6) | Grade 8 Female (n=8) |
|---|---|---|---|---|
| **Activity monitor counts (counts/min)** | 431.90 ± 76.80 | 320.50 ± 56.15 | 390.90 ± 74.10 | 385.60 ± 92.40 |
| **PAQ-C** | 3.60 ± 0.20 | 2.84 ± 0.20 | 3.40 ± 0.30 | 2.42 ± 0.30 |
| **Pearson's r** | -0.38 ($p = 0.46$) | 0.60 ($p = 0.08$) | 0.21 ($p = 0.68$) | 0.78 ($p < 0.03$) |

Mean ± SD

## Table 4.23 Regression analysis for aerobic fitness and BMI

| Group | Variable | Regression Equation | $R^2$ | p |
|---|---|---|---|---|
| **Grade 5 Males (n=42)** | **6MRD** (m) | -17.1 (BMI) + 1420.0 | 0.20 | 0.003 |
| | **6MRD/FFM** (m/kgFFM) | -1.9 (BMI) + 72.6 | 0.59 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.6 (BMI) + 57.7 | 0.20 | 0.003 |
| **Grade 5 Females (n=21)** | **6MRD** (m) | -21.1 (BMI) + 1338.0 | 0.18 | 0.06 |
| | **6MRD/FFM** (m/kgFFM) | -2.2 (BMI) + 75.6 | 0.66 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.7 (BMI) + 56.1 | 0.18 | 0.06 |
| **Grade 8 Males (n=32)** | **6MRD** (m) | -33.5 (BMI) + 1870.4 | 0.37 | 0.0002 |
| | **6MRD/FFM** (m/kgFFM) | -1.7 (BMI) + 65.1 | 0.65 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -1.1 (BMI) + 70.0 | 0.37 | 0.0002 |
| **Grade 8 Females (n=30)** | **6MRD** (m) | -21.1 (BMI) + 1473.4 | 0.20 | 0.01 |
| | **6MRD/FFM** (m/kgFFM) | -1.4 (BMI) + 57.0 | 0.58 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.7 (BMI) + 57.4 | 0.20 | 0.01 |

**Table 4.25 Regression analysis for aerobic fitness and %BF**

| Group | Variable | Regression Equation | $R^2$ | p |
|---|---|---|---|---|
| **Grade 5 Males (n=42)** | **6MRD** (m) | -7.2 (%BF) + 1263.0 | 0.15 | 0.01 |
| | **6MRD/FFM** (m/kgFFM) | -0.6 (%BF) + 50.3 | 0.25 | 0.001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.2 (%BF) + 52.5 | 0.15 | 0.010 |
| **Grade 5 Females (n=21)** | **6MRD** (m) | -12.0 (%BF) + 1277.4 | 0.13 | 0.11 |
| | **6MRD/FFM** (m/kgFFM) | -1.1 (%BF) + 65.0 | 0.36 | 0.004 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.4 (%BF) + 54.1 | 0.13 | 0.110 |
| **Grade 8 Males (n=32)** | **6MRD** (m) | -20.9 (%BF) + 1624.2 | 0.39 | 0.0001 |
| | **6MRD/FFM** (m/kgFFM) | -0.8 (%BF) + 46.0 | 0.38 | 0.002 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.7 (%BF) + 61.4 | 0.39 | 0.0001 |
| **Grade 8 Females (n=30)** | **6MRD** (m) | -22.0 (%BF) + 1706.0 | 0.40 | 0.0006 |
| | **6MRD/FFM** (m/kgFFM) | -1.1 (%BF) + 60.0 | 0.61 | 0.0001 |
| | **Predicted Peak $\dot{V}O_2$** ($ml.kg^{-1}.min^{-1}$) | -0.7 (%BF) + 65.2 | 0.40 | 0.0006 |

**Table 4.26 Estimated energy expenditure (kJ) calculated from six-minute running test distances – stratified according to the BMI categories of Cole *et al*. (2000)**

| Group | Estimated energy expenditure for participants with normal BMI (kJ) | Estimated energy expenditure for participants with a BMI classed as overweight/obese BMI (kJ) |
|---|---|---|
| **Grade 5 Males** | 151.3 ± 24.7* (n=30) | 176.7 ± 20.0 (n=12) |
| **Grade 5 Females** | 123.1 ± 27.4 (n=16) | 127.8 ± 32.1 (n=5) |
| **Grade 8 Males** | 227.3 ± 54.4 (n=20) | 234.6 ± 64.2 (n=12) |
| **Grade 8 Females** | 186.9 ± 30.7 (n=21) | 193.7 ± 21.1 (n=9) |

Mean ± SD
*significantly different from the overweight/obese BMI group ($p<0.01$)

**Table 4.27 Correlation analysis for aerobic fitness versus PAQ-C**

| Group | Variable | Pearson's r | p |
|---|---|---|---|
| **Grade 5 Males (n=42)** | **6MRD** (m) | 0.34 | 0.03 |
| | **6MRD/FFM** (m/kgFFM) | 0.17 | 0.35 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 0.34 | 0.03 |
| **Grade 5 Females (n=21)** | **6MRD** (m) | 0.32 | 0.15 |
| | **6MRD/FFM** (m/kgFFM) | 0.35 | 0.12 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 0.32 | 0.15 |
| **Grade 8 Males (n=32)** | **6MRD** (m) | 0.53 | 0.01 |
| | **6MRD/FFM** (m/kgFFM) | 0.31 | 0.08 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 0.53 | 0.01 |
| **Grade 8 Females (n=30)** | **6MRD** (m) | 0.32 | 0.09 |
| | **6MRD/FFM** (m/kgFFM) | 0.24 | 0.22 |
| | **Predicted Peak $\dot{V}$ $O_2$** ($ml.kg^{-1}.min^{-1}$) | 0.32 | 0.09 |

**Table 4.28 Correlation analysis for aerobic fitness versus activity monitor counts**

| Group | Variable | Pearson's r | p |
|---|---|---|---|
| **Grade 5 Males (n=6)** | **6MRD** (m) | -0.73 | 0.10 |
| | **6MRD/FFM** (m/kgFFM) | -0.51 | 0.30 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | -0.73 | 0.10 |
| **Grade 5 Females (n=9)** | **6MRD** (m) | 0.57 | 0.11 |
| | **6MRD/FFM** (m/kgFFM) | 0.18 | 0.64 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.57 | 0.11 |
| **Grade 8 Males (n=6)** | **6MRD** (m) | 0.27 | 0.61 |
| | **6MRD/FFM** (m/kgFFM) | 0.32 | 0.54 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.27 | 0.61 |
| **Grade 8 Females (n=8)** | **6MRD** (m) | 0.52 | 0.19 |
| | **6MRD/FFM** (m/kgFFM) | 0.50 | 0.21 |
| | **Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.52 | 0.19 |

**Table 4.29 Correlation analysis for aerobic fitness versus estimated MET**

| Group | Variable | Pearson's r | p |
|---|---|---|---|
| **Grade 5 Males (n=6)** | **6MRD** (m)<br>**6MRD/FFM** (m/kgFFM)<br>**Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | -0.76<br>-0.54<br>-0.76 | 0.08<br>0.27<br>0.08 |
| **Grade 5 Females (n=9)** | **6MRD** (m)<br>**6MRD/FFM** (m/kgFFM)<br>**Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.57<br>0.21<br>0.57 | 0.11<br>0.59<br>0.11 |
| **Grade 8 Males (n=6)** | **6MRD** (m)<br>**6MRD/FFM** (m/kgFFM)<br>**Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.25<br>0.31<br>0.25 | 0.63<br>0.54<br>0.63 |
| **Grade 8 Females (n=8)** | **6MRD** (m)<br>**6MRD/FFM** (m/kgFFM)<br>**Predicted Peak $\dot{V}$ $O_2$** (ml.kg$^{-1}$.min$^{-1}$) | 0.54<br>0.48<br>0.54 | 0.17<br>0.23<br>0.17 |

**Table 4.30 Physical activity measurements stratified according to the BMI categories of Cole *et al*. (2000)**

| Group | Variable | Normal BMI | Overweight/Obese BMI |
|---|---|---|---|
| **Grade 5 Males** | **PAQ-C** | 3.33 ± 0.60<br>(n = 30) | 3.33 ± 0.70<br>(n = 12) |
| **Grade 5 Females** | **PAQ-C** | 2.71 ± 0.40<br>(n = 16) | 2.60 ± 0.54<br>(n = 5) |
| **Grade 8 Males** | **PAQ-C** | 3.30 ± 0.64<br>(n = 20) | 2.74 ± 0.40<br>(n = 12) |
| **Grade 8 Females** | **PAQ-C** | 2.44 ± 0.72<br>(n = 21) | 2.30 ± 0.50<br>(n = 9) |

Mean ± SD

**Table 4.31 Regression analysis for PAQ-C and BMI**

| Group | PAQ-C = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males (n=42)** | -0.02 (BMI) + 3.64 | 0.01 | 0.54 |
| **Grade 5 Females (n=21)** | -0.02 (BMI) + 3.00 | 0.01 | 0.61 |
| **Grade 8 Males (n=32)** | -0.10 (BMI) + 4.56 | 0.20 | 0.01 |
| **Grade 8 Females (n=30)** | -0.03 (BMI) + 3.13 | 0.03 | 0.38 |

**Table 4.32 PAQ-C as categorised by %BF strata of Taylor *et al*. (2002)**

| Group | Variable | Normal %BF | Overweight %BF |
|---|---|---|---|
| **Grade 5 Males** | **PAQ-C** | 3.34 ± 0.70 (n = 22) | 3.33 ± 0.60 (n = 20) |
| **Grade 5 Females** | **PAQ-C** | 2.70 ± 0.40 (n = 14) | 2.70 ± 0.51 (n = 7) |
| **Grade 8 Males** | **PAQ-C** | 3.30 ± 0.64 (n = 19) | 2.67 ± 0.45 (n = 13) |
| **Grade 8 Females** | **PAQ-C** | 2.53 ± 0.72 (n = 19) | 2.14 ± 0.45 (n =11) |

Mean ± SD

**Table 4.33 Regression analysis for PAQ-C and %BF**

| Group | PAQ-C = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males (n=42)** | 0.001 (%BF) + 3.31 | 0.0000 | 0.97 |
| **Grade 5 Females (n=21)** | -0.01 (%BF) + 3.01 | 0.02 | 0.57 |
| **Grade 8 Males (n=32)** | -0.10 (%BF) + 4.20 | 0.29 | 0.001 |
| **Grade 8 Females (n=30)** | -0.03 (%BF) + 3.30 | 0.03 | 0.38 |

**Table 4.34 Regression analysis for BMI and %BF versus activity monitor counts**

| Group | activity monitor counts = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males (n=6)** | 44.40 (BMI) - 281.60<br>13.7 (%BF) + 189.2 | 0.41<br>0.16 | 0.17<br>0.43 |
| **Grade 5 Females (n=9)** | 0.32 (BMI) + 314.22<br>-3.6 (%BF) + 429.4 | 0.0001<br>0.01 | 0.99<br>0.76 |
| **Grade 8 Males (n=6)** | -13.12 (BMI) + 663.43<br>-5.6 (%BF) + 512.9 | 0.10<br>0.05 | 0.54<br>0.67 |
| **Grade 8 Females (n=8)** | -33.84 (BMI) + 1087.65<br>-23.7 (%BF) + 1089.3 | 0.07<br>0.13 | 0.52<br>0.37 |

**Table 4.35 Regression analysis for BMI and %BF versus estimated MET**

| Group | MET = | $R^2$ | p |
|---|---|---|---|
| **Grade 5 Males (n=6)** | 8.9 (BMI) – 3.7 | 0.48 | 0.13 |
| | -10.6 (%BF) – 6.0 | 0.16 | 0.43 |
| **Grade 5 Females (n=9)** | -1.1 (BMI) + 21.9 | 0.003 | 0.89 |
| | -5.6 (%BF) + 42.4 | 0.04 | 0.61 |
| **Grade 8 Males (n=6)** | -8.0 (BMI) + 36.2 | 0.11 | 0.53 |
| | -10.1 (%BF) + 41.1 | 0.06 | 0.64 |
| **Grade 8 Females (n=8)** | -1.60 (BMI) + 23.8 | 0.04 | 0.64 |
| | -4.70 (%BF) + 38.5 | 0.09 | 0.47 |

# Appendix N: Chapter 5 Appendices

**Table 5.2 Kolmogorov-Smirnov test results**

| Variable | N | Kolmogorov-Smirnov Z | Significance |
|---|---|---|---|
| **Age (years)** | 32 | 1.246 | 0.090 |
| **Height (cm)** | 32 | 0.361 | 0.999 |
| **Mass (kg)** | 32 | 0.639 | 0.808 |
| **Heart rate (bpm)** | 32 | 0.818 | 0.516 |
| **BMI ($kg/m^2$)** | 32 | 0.803 | 0.539 |
| **Peak $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)** | 32 | 0.667 | 0.765 |
| **PAQ-C** | 32 | 0.521 | 0.949 |
| **Activity Monitor Counts (counts/day)** | 16 | 1.132 | 0.154 |
| **$FEV_1$ (% predicted)** | 32 | 0.531 | 0.941 |
| **FVC (% predicted)** | 32 | 1.521 | 0.200 |

**Table 5.8 Amount of time and proportion of time spent in daily physical activity classified by intensity range**

| | Male (n = 9) | Female (n = 7) |
|---|---|---|
| **Light (mins/day)** | 533.3 ± 188.0 | 545.6 ± 176.0 |
| **Time %** | 55.6% | 56.8% |
| **Moderate (mins/day)** | 345.7 ± 158.7 | 342.0 ± 152.4 |
| **Time %** | 36.0% | 35.6% |
| **Vigorous (mins/day)** | 64.9 ± 36.2 | 61.2 ± 31.2 |
| **Time %** | 6.7% | 6.4% |
| **Extreme (mins/day)** | 16.1 ± 26.4 | 11.2 ± 10.02 |
| **Time %** | 1.7% | 1.2% |

Mean ± SD

**Table 5.9 Correlation analysis for activity monitor counts and PAQ-C**

| | Male (n=9) | Female (n=7) | All (n = 16) |
|---|---|---|---|
| **Activity Monitor Counts (counts/min)** | 302.9 ± 150.6 | 269.0 ± 60.6 | 288.1 ± 143.6 |
| **PAQ-C** | 3.27 ± 0.64 | 2.10 ± 0.92 | 2.78 ± 0.95 |
| **Pearson's r** | -0.26 (p = 0.51) | 0.73 (p = 0.10) | 0.03 (p = 0.97) |

Mean ± SD

## Table 5.14 Regression analysis for peak $\dot{V}O_2$ and physical activity

| Group | Regression Equation | $R^2$ | p |
|---|---|---|---|
| **Males** | Peak $\dot{V}O_2$ = 5.90 (PAQ-C) + 26.70 | 0.14 | 0.12 |
| | Peak $\dot{V}O_2$ = 0.05 (Activity Monitor Counts) + 43.90 | 0.02 | 0.69 |
| | Peak $\dot{V}O_2$ = 5.93 (MET) + 33.20 | 0.06 | 0.51 |
| **Females** | Peak $\dot{V}O_2$ = 3.32 (PAQ-C) + 34.40 | 0.22 | 0.09 |
| | Peak $\dot{V}O_2$ = 0.03 (Activity Monitor Counts) + 37.02 | 0.12 | 0.42 |
| | Peak $\dot{V}O_2$ = 6.43 (MET) + 31.35 | 0.08 | 0.54 |
| **All** | Peak $\dot{V}O_2$ = 4.10 (PAQ-C) + 32.52 | 0.19 | 0.01 |
| | Peak $\dot{V}O_2$ = 0.06 (Activity Monitor Counts) + 42.93 | 0.03 | 0.52 |
| | Peak $\dot{V}O_2$ = 6.22 (MET) + 32.24 | 0.007 | 0.31 |

## Table 5.16 Regression analysis for physical activity and BMI

| Group | Regression Equation | $R^2$ | p |
|---|---|---|---|
| **Males** | PAQ-C = -0.02 (BMI) + 3.52 | 0.02 | 0.57 |
| | Activity Monitor Counts = -21.7 (BMI) + 732.1 | 0.10 | 0.39 |
| | MET = -0.02 (BMI) + 2.50 | 0.04 | 0.59 |
| **Females** | PAQ-C = -0.05 (BMI) + 3.04 | 0.03 | 0.57 |
| | Activity Monitor Counts = -24.8 (BMI) + 743.1 | 0.56 | 0.10 |
| | MET = -0.08 (BMI) + 3.49 | 0.62 | 0.10 |
| **All** | PAQ-C = -0.04 (BMI) + 3.49 | 0.03 | 0.33 |
| | Activity Monitor Counts = -21.6 (BMI) + 709.7 | 0.11 | 0.19 |
| | MET = -0.03 (BMI) + 2.60 | 0.08 | 0.29 |

**Table 5.20 Multiple regression analyses - peak $\dot{V}O_2$, physical activity and forced expiratory ratio**

| Physical Activity Method | Regression Equation | $R^2$ | p |
|---|---|---|---|
| **PAQ-C** | Peak $\dot{V}O_2$ = 4.26 (PAQ-C) - 0.09 (FER) + 39.8 | 0.12 | 0.10 |
| **Activity Monitor Counts** | Peak $\dot{V}O_2$ = 0.009 (Activity Monitor Counts) + 0.35 (FER) + 11.0 | 0.12 | 0.43 |
| **MET** | Peak $\dot{V}O_2$ = 5.76 (MET) + 0.28 (FER) + 8.32 | 0.13 | 0.40 |