The effect of structured and lifestyle physical activity interventions on the bone health and body composition of 9-11 year old children

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Abstract

Childhood obesity is becoming increasingly prevalent in the UK and globally. Over the last 10 years, there has been a rise in prevalence of risk factors for health and a decline in physical activity. Obesity is major health risk factor for a number of other chronic diseases, some of which are prevalent in children. Regular physical activity is associated with reduced adiposity, healthier metabolic status lower risk factors of diabetes and CHD and enhanced bone mineral accrual and protection against osteoporosis. Recent literature suggests that children may not be meeting the recommended daily guideline for physical activity of 60 min per day (Riddoch et al., 2007), while others suggest this guideline is insufficient to protect against risk factors in children. Assessment of programmes promoting physical activity, with robust health related outcome measures are therefore warranted

Initially, sixty-one children were recruited for a 9-week exploratory trial. The trial assessed the effect of a structured high impact exercise (STEX) and a lifestyle intervention (PASS). Changes in dual-energy X-ray absorptiometry (DXA) derived body composition and bone mineral were compared to age matched controls (CONT). The STEX intervention resulted in an additional mean increase in total body BMC of 63.3 g ($P = 0.019$) and an additional increase of 0.011 g.cm^{-2} ($P = 0.018$) for BMD over changes observed in controls. Neither intervention stimulated significant increases in BMC or BMD at the femoral neck or lumbar spine ($P > 0.05$) compared with the controls. No significant changes were found in fat mass index ($P > 0.05$), lean mass index ($P > 0.05$) or percent body fat ($p = 0.09$) in any groups. Structured impact exercise promoted significant and clinically relevant increases in bone measures, without significant changes to body composition. The exploratory finding therefore supported the need for a larger, definitive randomised trial to confirm the results.

Following this, a large cohort of Liverpool school children (n=152) was recruited for cross-sectional analysis. Measures included 3-day physical activity using a uniaxial accelerometer, maturity status, cardio-respiratory fitness and skin-fold measurements in addition to body composition, bone mineral content and density. Analysis of variance was used to uncover any sex differences, partial correlation analysis was performed to investigate relationships between health-related variables and physical activity, with maturity offset as the controlling variable. Regression analysis was performed to find the best predictor of BMC and BMD (primary outcome variable), using LM, FM, Mass, and maturity offset as predictor variables. The results showed that children participated in the recommended amount of activity. However, body fat measures indicated that the children fell between the 85th-95% percentile for overweight. Further more BMD status of both sexes also fell below reference values. The dose-response relationship was highlighted as children who participated in <60 min.day^{-1} recommendation were less physically fit ($P=0.001$) and fatter ($P<0.001$) than children achieving this guideline. Children participating in over >90 min.day^{-1} had significantly lower percent body fat ($P=0.005$) and fat mass ($P=0.04$) than children who participated in <60 min.day^{-1} and significantly lower percent body fat ($P=0.02$)

than all children who participated in <90 min.day^{-1}. The findings highlight the importance of the high volume (>90 min.day^{-1}) and high-intensity physical activity (over 10 min.day^{-1}) as a precursor to low body fat and high bone mineral in children.

The one hundred and fifty-two children from the baseline cohort were allocated to 1 of 4 groups over a 12 month period. Three groups received a different physical activity intervention; a high-intensity programme ('HIPA'), a skill development programme ('FMS') or a lifestyle-based programme ('PASS'). The 'HIPA' and 'FMS' groups participated in an after-school club (2x60 min.week^{-1}), the 'PASS' group attended weekly classroom sessions (1 x week) delivered by a lifestyle coach during the school day. The control group ('CONT') received health information. All baseline measures were repeated at 9 and 12 months (during and after) intervention. All interventions minimised fat mass accumulation, with the 'HIPA' intervention being most effective (P=0.03), implying that the high-intensity nature of the activity sessions was more effective at minimising body fat accumulation. The greatest magnitude of change in femoral neck BMC (P<0.001) and BMD (P<0.001) and cardio-respiratory fitness (P=0.023) was also reported by the 'HIPA' group which is likely to be attributable to the intensity of the weight-bearing activities included in the 'HIPA' programme. The findings suggested that the 'HIPA' intervention was most beneficial for health outcomes, but all interventions had significant effect on increasing time spent in physical activity.

The studies within this thesis have provided a unique insight in to the current bone health status, body composition and physical activity of 9-11 year old Liverpool school children. Further data were also generated on the effect of different physical activity interventions on bone health, body composition and physical activity. The findings from this thesis conclude that a proportion of 9-11 year old children were overweight despite meeting physical activity recommendations of 60 min.day^{-1}. The high-intensity physical activity intervention had the most beneficial impact on bone health, body composition and cardio-respiratory fitness when compared to the controls. The quantity of physical activity and the time spent in high intensity activity warrants further investigation to quantify an optimal dose.

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In memory of Tom Reilly

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Glossary

Bone measurement

BMC	Bone Mineral Content (g)
BMC$_{TB}$	Bone Mineral Content of total body (g)
BMC$_{FN}$	Bone Mineral Content of the femoral neck (g)
BMC$_{LS}$	Bone Mineral Content of the lumbar spine, L1-L4 (g)
BMD	Bone Mineral Density (g.cm^{-1})
BMD$_{TB}$	Bone Mineral Density of total body (g.cm^{-1})
BMD$_{FN}$	Bone Mineral Density of the femoral neck (g.cm^{-1})
BMD$_{LS}$	Bone Mineral Density of the lumbar spine, L1-L4 (g.cm^{-1})
DXA	Dual-Energy X-ray Absorptiometer

Body Composition

FM	Fat Mass (g)
LM	Lean Mass (g)
%BF	Body Fat Percent (%)
SF	Skin-fold thickness
∑4SF	Sum of 4 skin-fold thicknesses (triceps, subscapular, supraspinale, medical calf)
∑7SF	Sum of 7 skin-fold thicknesses (triceps, subscapular, biceps, supraspinale, abdomen, front thigh and medial calf)
∑8SF	Sum of 8 skin-fold thicknesses (triceps, subscapular, biceps, iliac crest, supraspinale, abdomen, front thigh and medial calf)
ISAK	International Society for Advancement in kinanthropometry
BMI	Body Mass Index (kg/m^2)

Physical Activity

PA	Physical Activity
HPA	Habitual Physical Activity
MPA	Moderate Intensity Physical Activity
MVPA	Moderate-to-vigorous Intensity Physical Activity
VPA	Vigorous Intensity Physical Activity
HR	Heart Rate
HR$_{max}$	Maximum Heart Rate

Fitness

$\dot{V}O_{2Peak}$	Peak Oxygen Uptake (ml.kg^{-1}.min^{-1})

Research design

A-CLASS	**A**ctive **C**ity of **L**iverpool **A**ctive **S**chools and **S**portsLinx
IMD	Index of Multiple Deprivation
SES	Socio-economic status
STEX	Structured exercise (group – Study 1)
HIPA	High Intensity Physical activity
FMS	Fundamental Movement Skill
PASS	Physical Activity Signposting Scheme
CONT	Control

Statistical

ANOVA	Analysis of variance
ANCOVA	Analysis of Covariance
95% CI	95% Confidence Interval
Δ	Change
SD	Standard Deviation
n	Sample size
MCID	Minimum Clinical Importance Difference

Declaration

I declare that the work contained in this thesis is entirely my own.

Signed

Chapter

1

Introduction

1.0 Introduction

Are physical activity levels in children declining? Does this decline have a negative impact on bone health, body composition and fitness? Can bone health, body composition and fitness be influenced positively by physical activity interventions? Such questions are prevalent within paediatric research and the public health arena. In the first instance, this thesis will focus the research problem to provide the aims and objectives of this thesis. A comprehensive review of literature will follow which will inform the reader of the current state of children's health, the relationships between physical activity, bone, body composition and fitness and the outcomes of intervention research to date. The studies that feature in this thesis were designed with the gaps in the current literature in mind. Ultimately, this thesis will assess the effect of different types of physical activity intervention on bone, body composition and fitness parameters, and more specifically will attempt to quantify the volume and intensity of activity required to maximise the physiological benefits gained from physical activity. The requirement for such information is necessary to address the physical activity levels of young people, particularly given the incidence of health risk amongst children and adults in today's society.

"Only 37% of men and 24% of women are sufficiently active to gain any health benefit".

Department of Health (DoH), 2004

In 5955 11 year old children, only 2.5% (boys 5.1%, girls 0.4%) met current internationally recognised recommendations for physical activity, when physical activity was objectively measured.

Riddoch et al., (2007)

The prevalence of obesity in adults trebled from 1980 to 2000; In 2000; 5.5% of boys were obese and 22% overweight, 7.2% girls were obese and 28% overweight.

Health Survey for England (HSE, 2002) Rennie & Jebb (2005)

Childhood overweight and obesity increased from 13% to 20% over 4-years. In 5-17 year olds; 10-15% of boys and 15-20% of girls were overweight or obese. In 7-11 year olds, overweight or obesity increased to 17% in boys and 23% in girls

HSE 1994-1998 Lobstein *et al.*, (2003).

Central adiposity reported in children as young as 6 and 7 years old.

Moreno *et al.*, (2001)

These findings and statements confirm that the current status of health within the UK and worldwide has declined over the past ten years. Physical activity is regarded an integral factor in health maintenance, but epidemiological data suggest that the population as a whole are not active enough to accrue these benefits. Regular physical activity can promote the reduction of body fat, increase lean tissue mass; provide healthier metabolic status thus reduce health risk factors such as diabetes and coronary heart disease (CHD) and also enhance bone mineral accrual and delay the onset of musculoskeletal disorders such as osteoporosis. Although recent findings from a large European sample suggest that the increase in adult obesity rates are not due to physical activity decline (Westerterp and Speakman, 2008). Current UK findings suggest that levels of PA in children and adults have fallen and prevalence of health risk parameters (including obesity) have risen (HSE, 2002; DoH, 2003., 2004). An increase in the prevalence of obesity in children causes most concern for future public health. The WHO (2006) predicted that childhood obesity was associated with an increased prevalence of premature death and disability in adulthood. This is largely because overweight and obesity are also major health risk factors for a number of other chronic diseases, including cardiovascular diseases, musculoskeletal disorders, type II diabetes and some cancers (WHO, 2006). Some risk factors have been found to be prevalent in children and have been linked to body fatness (Gutin *et al.*, 1994; Rizzo *et al.*, 2007) and level of physical activity (Andersen *et al.*, 2006).

The distribution of fat, particularly centrally distributed fat is regarded as an independent health risk factor and is associated with greater risk of morbidity and mortality, particularly clustered cardiovascular risk in adults (Lemieux *et al.*, 2000 - McCarthy) and children (Freedman *et al.*, 1999; Andersen *et al.*, 2008). Abdominal adiposity and physical activity are independently associated with cluster risk (Andersen *et al.*, 2008), and thus supports the emphasis of the promotion of physical activity to children to reduce cardiovascular and overall health risk (Klein-Platat *et al.*, 2005). The rapid increase in overweight for 7-11 year old children (Lobstein *et al.*, 2003) and the development of excess abdominal fat in children as young as 6-years old (Moreno *et al.*, 2001) articulates that the entire paediatric population may be at a potential health risk.

The skeletal disease of osteoporosis is a chronic condition and concerns loss of bone mass and increased the risk of fracture. Regular weight-bearing activity is thought protect against fracture risk and delay the onset of osteoporosis as loading activities increase bone mineral properties through bone remodelling. The importance of good bone health in children is that childhood is the most beneficial time to maximise bone mass (Bass *et al.*, 1998., MacKelvie *et al.*, 2002). In particular, the pre (Bass *et al.*, 1998) and early pubertal (MacKelvie *et al.*, 2002) years are the most important for maximising bone gains through physical activity.

Given the benefits of physical activity, particularly the reduction of morbidity and mortality, if recommended physical activity guideline of 60 min per day is not met (DoH, 2003) the incident of risk factor development seems imminent. Cross-sectional studies indicate that children who are more active tend to have lower body fat (Abbot and Davies, 2004; Ness *et al.*, 2007; Saelens *et al.*, 2007) than their less active counterparts. The intensity and volume of activity are suggested to be key components; many propose vigorous physical activity to be the most important physical activity behaviour responsible for fatness (Patrick *et al.*, 2006; Ruiz *et al.*, 2006). Positive associations between mechanical loading from physical activity on bone mineral content and bone mineral density in children have also been identified in cross sectional (Bass *et al.*, 1998, Scarpella *et al.*, 2002., Greene *et al.*, 2005.) and intervention research (Gutin *et al*,. 1999.; Fuchs *et al.*, 2001.; MacKelvie *et al.*, 2003). The relationship between lean mass increases and bone mineral accrual is also well documented (Vicente-Rodrigues *et al.*, 2005;Tobias *et al.*, 2007). Lean tissue mass has also been reported as the strongest determinant of bone mineral density in many studies (Uusi-Rasi *et al.*, 1997; Crabtree *et al.*, 2004; Vicente-Rodriguz *et al.*, 2005) which further supports the notion of bone health-related benefits in body composition from physical activity and the need for interventions that will promote lean mass gains as well as fat reduction and bone mineral accrual.

A recent systematic review of 33 research trials in children found a lack of quality physical activity interventions (van Sluijs *et al.*, 2007). The overall effectiveness of intervention trials is difficult to determine due to the variability and quality of the intervention design, which in itself affects the intervention's ecological validity. Limitations within the current research lie within the methodologies and study design. Despite the evidence that adequate physical activity during childhood can be beneficial to adult health in terms of bone, body composition and cardiovascular benefits, the evidence is not definitive due to the lack of studies that objectively assess physical activity combined with sensitive measures of health markers.

The diversity of intervention programme design and accuracy of assessment methods in intervention and cross-section research often makes it difficult to draw clear causal relationships. Population specific research (e.g. obese) is necessary, but cannot be generalised to the whole population. There is also a lack of longitudinal studies in this area, such studies provide little evidence that positive gains in bone mineral can be maintained into adulthood and reduce the risk of morbidity. Within bone research, retrospective studies support the long-term positive effects of weight-bearing activity (Bass *et al.*, 1998., Kahn *et al.*, 1998), while others provide evidence that no was benefit gained (Karlsson *et al.*, 2000). Regardless of this, retrospective data cannot provide proof of causality and therefore the long-term benefit of increased bone mineral during childhood remains unclear. There are also questions of whether interventions that enhance bone mineral accrual are only accelerating the achievement of a pre-determined bone mass (MacKelvie, 2002).

The type of intervention (exercise, lifestyle, education) and environment where the intervention is delivered (School, home, community) are diverse. Exercise interventions are abundant in the literature, but there is little evidence that any positive gains can be maintained after the intervention has finished. Lifestyle and education interventions may hold more ecological weight than structured exercise interventions, but they are often broad, difficult to monitor and difficult to identify which key elements if any, are successful. There is also a lack of studies examining the single and combined effect of exercise and lifestyle and/or education programmes. Schools are commonly used in paediatric intervention research because the school environment provides a health education infrastructure through the formal curriculum. School-based settings also benefit adherence to intervention due to reinforcement and support from the school. There is however evidence that school-based interventions have limited success at increasing out of school physical activity (Stone *et al.*, 1998) and are only beneficial when the intervention is additional to- rather than a substitution of- curriculum physical education (Almond and Harris, 1998). Although the latter promotes the importance of extra-curricular activity in school as an ideal medium for improving activity levels and promoting health benefits, the main limiting factor is that after-school activity is non-compulsory and may not reach those children who may benefit most of all.

The length of intervention also adds to the complexity of this area, and needs to be considered when comparing findings. Long-term intervention programmes may be more effective than shorter studies, but participation within the programme may be practically difficult due to parental commitment and/or boredom. Short or medium-term programmes on the other hand may be more enjoyable and adherence may be better, but may not be long enough to provide clinical evidence of effect within the intervention trial

With the consideration of all the limitations and contemporary debates surrounding intervention research, the effectiveness and optimal design of physical activity interventions on bone mineral enhancement and body fat remains unclear. School-based interventions appear to be the best method of achieving optimal adherence and support. In order to promote sustained physical activity, successful interventions should be integrated into the school day in addition to curriculum PE. The design of school-based interventions is therefore complex, apart from the participants, the support of parent and schools, problematic intervention logistics and appropriate programming to avoid boredom and sustain motivation during the intervention are key considerations. The intervention design must be feasible and suitable in the school setting, offering minimal disruption in-school and practical timetabling for optimal parental support after-school. Perhaps most importantly, programmes should be designed to encourage and promote physical activity to all children as a positive behaviour, one that will promote sustainable levels of adequate physical activity resulting in lifelong health benefits. Despite the limited large-scale longitudinal paediatric research to confirm Blair's *et al* (1989) relationships (Boreham and Riddoch, 2001), the belief that regular physical activity during childhood may contribute to long-term health benefits and reduce susceptibility to early onset of chronic disease in adulthood is heavily supported (Lui-Ambrose *et al.*, 2001, Abbott and Davies., 2002, Andersen *et al.*, 2006).

In 2005, one third of Liverpool primary school children aged 9-10 years were overweight or obese (SportsLinx, 2005), which supports Lobstein *et al*'s (2003) inference that children aged 7-11 may be particularly susceptible to behaviours resulting in excess body weight. From the supporting literature, it could be speculated that increased risk of Liverpool children developing obesity-related diseases in youth and later life is probable. The government action plan "Choosing Activity" (DoH, 2005) has allocated significant amounts of resource to schools to enforce prevention of overweight and obesity in children under 11 years old, through physical activity, education and nutritional advice (DoH, 2005). The implementation of a pragmatic intervention to increase children's activity levels requires investigation. Increasing volume and intensity of activity through exercise sessions and lifestyle home-based activity schemes is proposed to stimulate positive changes in bone health, body composition and increase physical activity levels of Liverpool primary school children.

The major aims of this thesis are to:

- Investigate the extent to which structured physical activity and lifestyle-based physical activity affects bone health and body composition over a 9 week period (feasibility study).
- Assess the current bone health status, physical activity and body composition of a sample of Liverpool school children
- Investigate the extent to which structured physical activity and lifestyle-based physical activity affects bone health and body composition over a 12 month period

The above aims will be achieved through the following objectives:

- To deliver a 9 week feasibility (exploratory trial) intervention, implementing a structured physical activity and a lifestyle-based physical activity intervention, assessing bone health and body composition before and post-intervention.
- Collate data related to bone health, body composition and PA in a small cross-sectional group of Liverpool school children.
- To deliver a 12-month physical activity intervention, implementing 3 different types of intervention and assessing bone health and body composition at before, during and post intervention.

Chapter
2

Review of Literature

2.0 Introduction

The purpose of this chapter is to review the current global literature concerning, bone health and body composition in children and adolescents. Our initial theoretical stand point prior to data collection is that exercise, as a dose, has a positive impact on bone mineral accrual (see figure 2.1.). Bone mineral health and body composition, will be the main focus of this chapter presenting sufficient information required to generate a rationale for this thesis.

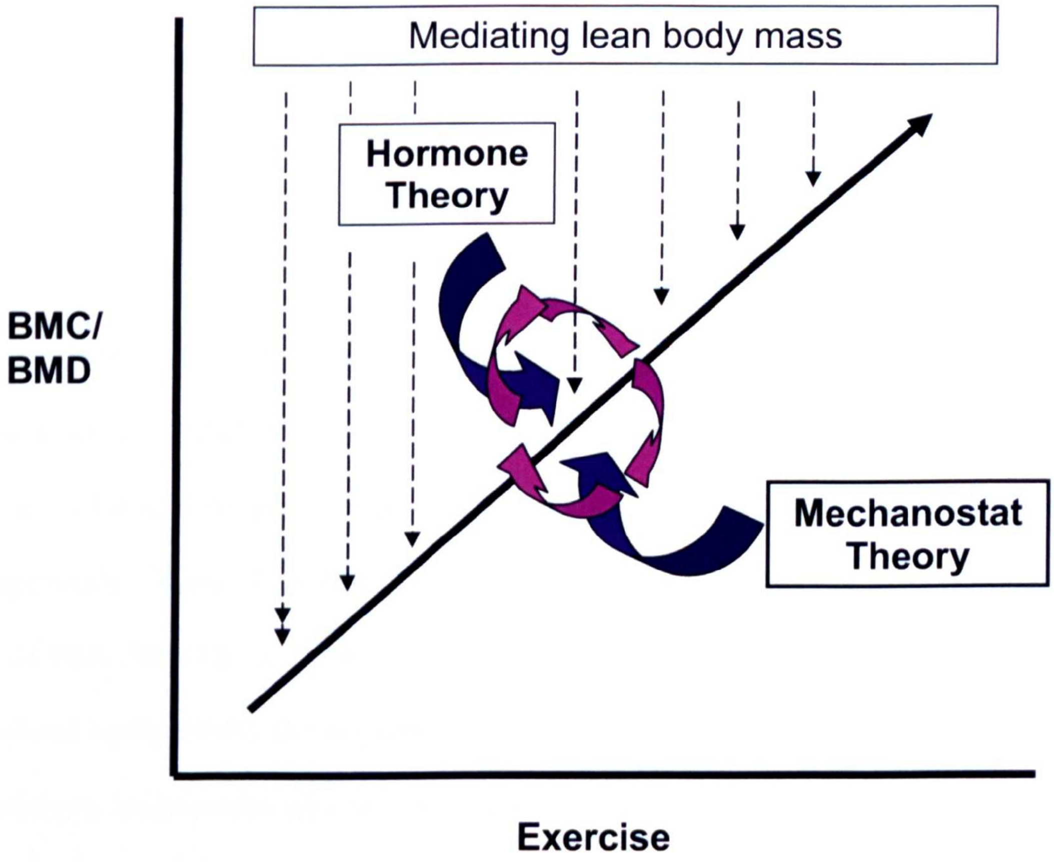


Figure 2.1 Theoretical Model: Exercise has a positive impact on bone mineral accrual

2.1 Theoretical background

2.1.1 Bone

The human body comprise of organs, bone, muscular tissue, adipose (fat) tissue and blood. Structurally the skeleton consists of 206 bones, and has 5 main functions; **support**: frame for the body accounting for 98% of stature, **protection**: of internal organs, **production**: of blood cells within bone marrow, **mineral storage**: a reservoir of calcium and phosphate, and finally **locomotion**: providing support for movement. The latter is achieved through lever movements controlled by muscles which are attached to bone; collectively this is called the musculoskeletal system. Skeletal muscle (lean tissue) generates movement through muscular contraction utilising energy from stores within the muscle, applying force to bones and joints resulting in general movement.

Bones constitute approximately 15-17% of body mass depending on age (Malina *et al.*, 2004); the remainder is made up of organs, muscle and fat tissue. Bone is a dynamic tissue that is composed of organic and inorganic components. Type 1 collagen largely (90%) contributes to the organic component forming a protein network which gives the bone matrix its structural component. Bone cells are also included in the organic make-up; osteoclast, osteoblasts and osteocytes will be discussed later in this section. The inorganic component of bone is hydroxyapatite [$Ca_{10}(PO_4)_6OH_2$] which is a mineral composed of **calcium** and **phosphate**. The human skeleton stores 99% of the body's calcium within this compound.

The skeleton consists of two types of bone: - cortical (compact bone) and trabecular (spongy/cancellous bone). Cortical bone is made of dense, calcified tissue and located on the exterior of bone and along the bone length. Its main function is to provide structure and protection and represents approximately 80% of skeletal mass and approximately 3% of cortical bone is renewed each year (Watts, 1999).

The remaining 20% is trabecular bone, which has lower calcium content, is less dense than cortical bone and is characterised by its honeycomb-like appearance. The large surface area provided by this structure serves as an exchange reservoir for minerals. This characteristic of spongy bone serves to provide a connection between the endosteum and bone marrow, blood vessels and connective tissue for metabolic purposes (Khan *et al.*, 2001). Trabecular bone is more metabolically active than cortical bone and more rapidly remodelled, approximately 25% of trabecular bone is renewed each year (Watts, 1999). Trabecular bone is located toward the end of long bones namely intertrocanteric region of proximal femur (femoral neck region), femoral shaft, distal radius and mid-radius and spinal vertebrae. It is suggested that regions with high proportions of trabecular bone (vertebrae and femoral neck) are known to respond fastest to changes in mechanical load (Heinonen *et al.*, 2000; Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001, 2003) but it may also be more susceptible to bone loss through inactivity and therefore fracture may be more likely. It is such regional sites that are of interest to this thesis, because these sites have the greatest prevalence of fracture (National Osteoporosis Society Online, 2006). There is also evidence that non-site specific bone adaptation can occur, where bone adaptation has occurred at a different site to which mechanical load was sustained in mice (Zhang *et al.*, 2006), however at present there is little supporting research to confirm this theory.

The growth of skeletal bone is influenced by endocrinal and mechanical factors (Kemper *et al.*, 2000). Three types of bone cell are involved in this constant remodelling process; **osteoclast**, **osteoblasts** and **osteocytes**. Bone remodelling is a regional response to a variety of environmental signals including **chemical** and **mechanical** (Forwood *et al.*, 2001) which subsequently alters bone mineral density and bone mass, therefore increasing bone strength.. The process of modelling and remodelling is lifelong, occurring during growth (at differing rates) and continuing through adulthood.

Osteoclasts are responsible for bone resorption which involves removing the bone's mineralised matrix (old bone) by dissolving bone mineral and digesting the bone matrix. Osteoblasts are responsible for bone formation by producing bone matrix, which is composed of mainly collagen. Osteoblasts mature after calcification has occurred and become osteocytes. These mature bone cells are embedded within the bone matrix and regulate the mineral and nutrient flow between the matrix and the bone (Malina *et al.*, 2004) and facilitate cellular communication regarding bone loading (Khan *et al.*, 2001). The interaction between osteoclasts and osteoblasts is fundamental to resorption and formation of bone within the dynamic remodelling process, balancing the production of new bone matrix and the removal (resportion) of mineralised (old) bone matrix. Resorption initiates formation restoring lost bone and supporting the process of bone remodelling (Khan *et al.*, 2001).

Bone-related intervention research often aims to investigate how bone parameters respond over a set period of time to different bone-stimulating exercises that vary in type, intensity, volume and duration. According to Frost (1985) and Watts (1999), this time period (duration) should be greater than 12 weeks to allow for the full cycle of activation-resportion and formation to occur. The remodelling process can be detected by biochemical markers for resoprtion and formation such as enzymes, proteins and by-products in blood or urine samples (Watts, 1999). The use of markers clinically is to diagnose or monitor disease/disorders, and markers can also be used to detect bone mineral changes from a chemical level. Bone biomarkers reflect the metabolic activity of the entire skeleton and is an inexpensive method of detecting changes (Watts, 1999), but although non-invasive per se, urine and blood sampling may not be appropriate in young children.

The **endocrine system** regulates and influences bone through the production of **hormones** controlling serum calcium levels. Sex hormones, oestrogen and testosterone play a key part in bone mineral production. Oestrogens are a group of steroid compounds that function as the primary female sex hormone, but they are present in both males and females (levels are significantly higher in females). Oestrogens help maintain bone mass by suppressing the activity of osteoclasts. Exercise or physical activity elevates the level of oestrogens, therefore reducing osteoclast activity. The reduction of osteoclast activity in turn increases bone mass, which causes more calcium (Ca^{2+}) and phosphorus (P) to be reabsorbed from the blood. This reduction of serum Ca^{2+} and P causes' vitamin D production to be inhibited which in turn stimulates calcium adsorption and a reduction of calcium secretion (Kemper *et al.*, 2000). This chemical process therefore supports mineral production and increases bone mass.

Testosterone is the primary male sex hormone, but is present in males and females. The adult male body produces approximately twice as much testosterone than the adult female body. Testosterone is an androgen; an anabolic steroid. Testosterone therefore affects the growth of muscle mass, promotes increased bone density and strength, and stimulation of linear growth and bone maturation.

Mechanostranduction is the process describing the influence mechanical stimuli has on bone cells and bone mineral turnover. Bone is subjected to stress caused by mechanical stimulus from weight-bearing activity through both muscle and ground reaction forces, this stress causes microtrauma. Such microtrauma stimulates bone growth and remodelling where osteoclasts remove damaged structures and osteoblasts repair the bone matrix. Skeletal muscle (lean mass) serves to place stress on the skeleton via a series of attachments and articulations around its system of levers.

Strain caused by forces applied to the bone through gravity and locomotion through muscle contraction has an osteogenic effect (French *et al.*, 2000., Janz *et al.*, 2004). It is believed that the contractile forces placed on the bone by the muscle that generate the largest load compared to gravitational forces (Frost and Schonau, 2000; Rauch *et al.*, 2004). Studies with weight-training groups compared to running (Snow-Harter *et al.*, 1992) found no significant differences between groups, whereas when weight training was compared to a control, significant differences in bone mineral accrual were observed (Witzke *et al.*, 2000), although studies involved adult populations.

Physical activity can therefore improve musculoskeletal health through remodelling of bone by imposing extra strain from muscle contraction. Rauch *et al* (2004) concluded and confirmed the "Mechanostat" theory; that muscle development proceeds bone development during pubertal growth (Rauch *et al.*, 2004), therefore if lean mass (muscle) is increased through physical activity, the contractile forces placed on the bone by the muscle is potentially greater; therefore increased lean mass indirectly enhances bone mineral properties (Rauch *et al.*, 2004; Tobias *et al.*, 2007). Evidence that lean mass is the strongest determinant of bone mineral density is supported throughout the literature (Uusi-Rasi *et al.*, 1997; Crabtree *et al.*, 2004; Vicente-Rodriguz *et al.*, 2005).

Bone "health" is often described or estimated using measures such as bone mineral content and bone mineral density. **Bone mineral content** (BMC) is the total amount of bone mineral measured in grams. **Bone mineral density**

(BMD) refers to the grams of bone mineral in a defined unit of bone area (g.cm^{-2}). A determinant of bone mineral properties is bone mass (Khan *et al.*, 2001). Bone mass and bone size are linked to bone strength, which is primarily a function of density. Peak bone mass is a term used that can be defined as the maximum amount of bone mass achieved at a given skeletal site as a result of normal growth (Matkovic and Landoll, 2000) and is therefore an important determinant of osteoporotic fracture risk in adulthood (Bonjour., 1995).

Bone mineral density is commonly used to describe bone "health" but has been criticised for its accuracy in paediatric research due to variation in skeletal growth. Change in skeletal size can bring about changes in bone strength in addition to enhanced BMD; therefore it is not appropriate to measure only whole-body BMD as an index of bone health. As well as whole-body bone parameters, regional bone sites are of great interest particularly in osteoporosis diagnosis (NOS online, 2006). Mechanical loading at sites such as the femoral neck and lumbar spine (L1-L4) in addition to whole-body assessment are frequently measured in research (Boot *et al.*, 1997; McKelvie *et al.* 2003; MacKay *et al.*, 2005; Wang *et al.*, 2005; Tobias *et al.*, 2007). Loading sites are susceptiible to loss in trabecular bone and the incidence of fracture (NOS online, 2006).

Dual energy X-ray absorptiometry (DXA) is a gold standard method used to measure bone mineral indices and is often used in bone related research and clinical practice. Subjects are exposed to a low dose of radiation (≤1.5 x

10-2 mSV; Mattison and Thomas, 2006) from two photon beam that pass through the body during a whole-body or regional scan and measures the cross-sectional area of bone and mineral content. The DXA scan provides data on BMC, BMD and bone area (BA), but as BMD is estimated from BMC and bone area (BA), the DXA output reports areal BMD estimation, as volume determinations cannot be made (Khan *et al.*, 2001). A whole-body scan can take 4-20 minutes depending on the model. Estimates of bone mineral and soft tissue are derived using algorithms from DXA computer software packages.

2.1.2 Body composition

Body composition is the umbrella term used to describe the basic components that quantify total body mass (weight). It has been suggested that the body can be assessed on five levels; Atomic, molecular, cellular, tissue and whole-body (Wang *et al.*, 1992). For the purpose of this thesis, body composition will be addressed using the three-component model, where total boy mass consists of lean body mass, bone mass and fat mass. All three components can be estimated by DXA. **Total fat mass** includes all body fat (essential or non essential adipose tissue), both visceral and subcutaneous. Dual energy X-ray absorptiometry is able to produce segmental data of the arms (right and left), legs (right and left), trunk, and head regions to provide fat distribution data. The term fat-free mass (FFM) is the remainder of mass after all fat is removed which includes fat free muscle mass, fat free bone, fat free adipose tissue (Hawes and Martin, 2001). **Lean mass** (LM) is slightly different again, estimated by DXA, lean mass is mineral-free (BMC), fat-free mass, it includes muscle, connective tissue and skin, it therefore is not entirely fat-free as it still contains compound lipids. Percentage body fat refers to the proportion of fat mass (FM) relative to body mass (BM) and is expressed as the percentage: FM/BM *100 = % Body Fat. This measure is commonly used in literature to describe body fatness in adults (Bosy-Westphal *et al.*, 2006) and children (Child Growth Foundation, 2005; McCarthy *et al.*, 2006)..

There are various ways to measure body fat in order to define if an individual has an excessive amount and thus can be classified as overweight or obese. Sophisticated assessment tools such as DXA and hydro-densitometry are commonly used as *in vivo* methods in research to assess fat mass (FM) and lean tissue mass (LM) objectively. Dual-energy X-ray absorptiometry has been validated against hydro-densitometry (Wallace *et al.*, 2007., Clark *et al.*, 1993) for fat mass assessment but has only been verified by animal cadaver analysis (Suster *et al.*, 2006), not human.

The most commonly used field-based methods of measuring adiposity are **body mass index** (BMI), skin-fold thicknesses and girth measurements, in particular waist and waist-to-hip ratio. Body mass index (BMI) is derived from a calculation (kg/m^2) that represents body mass (kg) relative to body stature (m). This surrogate index is frequently used in the public health domain as a marker for health because it is quick,and easy to calculate, although it does not directly measure body fat. Overweight and obesity are classified in adults as a BMI of above 25 and over 30 respectively (DoH, 2006). Divergent definitions of BMI overweight and obese cut-points for children are present in the literature, Cole *et al.* (2000) presented cut-points for boys and girls that are higher than those defined by Chinn and Rona, (2004), which are more conservative, yet both are used widely in literature. For example, a 10 year old boy, a BMI of 19.84 would be considered overweight, and 24 would be obese according to Cole *et al* (2000), where as a BMI of 18.8 and 22.7 are considered overweight and obese according to the Chinn and Rona (2004) cut-points. The definitions of Cole *et al.* (2000) are, however, derived from an international data set, whereas the cut-points of Chinn and Rona (2004) are obtained from a UK data set. The use of BMI as a marker for overweight and obesity remains a contentious issue; BMI does not distinguish fat from bone or muscle (McCarthy *et al.*, 2006) and therefore overestimates fatness in muscular or athletic individuals (Prentice and Jebb, 2001). Its use in children is particularly controversial due to different cut-off points and also the effect of growth and maturity during childhood that can occur at vastly different rates and times.

The complex changes in body size, shape and hormonal secretion that occur during puberty effect body composition; boys tend to increase lean mass due to increased testosterone production, girls are likely to increase fat mass due to increased oestrogen secretion. Burton (2007) questioned the validity of BMI because of is the use of height^2 and believes that BMI would be more sensitive if height was cubed, to account for build. The BMI also fails to indicate fat distribution which, given the association between abdominal adiposity and CVD risk (Andersen *et al.*, 2008), is a limitation of this method.

However, paediatric validation studies assessing children's BMI and body fat percentage and total fat mass from DXA (Mei *et al.*, 2002; Eissenman *et al.*, 2004) support the use of BMI as a measure of adiposity. Mei *et al.* (2002) found correlations in region of 0.7 and 0.8 for total fat mass and BMI and percentage body fat and BMI respectively, and a correlation coefficient of 0.9 when an overweight subgroup was analysed. There is still a common consensus that, amongst children, BMI may not be a sensitive indicator of fatness (Reilly *et al.*, 2000), and the interpretation of BMI in children of different ages should be made very carefully. Children of the same chronological age will have different biological ages and therefore maturation, or more visibly growth, will occur at different time points. Freedman *et al.* (2004) believed the effect of growth on BMI may not be significant before the age of 12 years; this is because height and adiposity are highly correlated before this age.

Skin-fold thickness assessment is useful in assessing total body fat and body fat distribution. The accuracy of skin-fold thickness for predicting overall adiposity in children and adolescents, however, is unclear; Watts *et al.* (2006) found skin-folds were poorly predictive of DXA derived total fat in obese children. Conversely, Steinberger *et al.* (2005) established strong correlations between skin-fold calculation estimates and DXA estimations amongst non-overweight adolescents. A reason for this contradiction could be that skin-fold estimations have been found to be less accurate in overweight or obese children compared to non-overweight children (Mei *et al.*, 2006; Freedman *et al.*, 2007). Lazzer *et al.* (2005) found that compared to the DXA method, the skin-fold method overestimates fat mass in boys and underestimated fat mass in girls. To avoid erroneous data, skin-fold assessment should only be executed by trained personnel and repeated measures are required. The number of skin-fold sites used to predict adiposity is also ambiguous and differs greatly in literature (Eston and Reilly, 2009).

The distribution of body fat, rather than total body fat has also been shown to be a key component in risk related to obesity (Andersen *et al.*, 2008). **Waist circumference** and **waist-to-hip ratio** (WHR) are used widely in epidemiological research as they provide a quick, simple field-measure of central adiposity in children (Lemieux *et al.*, 2000; Taylor *et al.*, 2000; McCarthy *et al.*, 2001, 2003; Webster-Gandy *et al.*, 2003; Andersen *et al.*, 2008). As marker for abdominal fat, waist circumference and waist-to-hip ratio are highly correlated with abdominal fat measured by DXA (Snijder *et al.*, 2002). Central adiposity measured by waist circumference is associated with clustered cardio-vascular disease risk (Andersen *et al.*, 2008). Many studies have proposed that waist-to-hip ratio (McCarthy *et al.*, 2003; Yusuf *et al.*, 2005) and waist circumference (Savva *et al.*, 2000; Yusuf *et al.*, 2005) are better predictor of health risk than BMI or whole body fat. As to which measure (waist circumference or WHR) is most predictive of risk elevation remains unclear.

2.1.3 Physical activity

Physical activity is defined as "any bodily movement produced by skeletal muscles that result in energy expenditure above basal metabolic rate" (Bouchard *et al.*, 1990). Time spent participating in physical activity is measured to assess quantity. Physical activity can be examined by intensity of activity e.g. sedentary, low, moderate or vigorous, where investigators can assess the proportion of time spend in each. Assessment of habitual physical activity can help investigators explore the quantity daily activity and how that can contribute towards specific markers such as health. The amount of physical activity a person participates in is termed as a dose. The dose includes the characteristics of frequency (number of activity sessions per unit of time e.g week), duration (number of minutes of activity in each session), intensity (effort level of the activity) and the type of activity (Howley, 2001). Relationships between physical activity and health outcomes are often referred to dose-response relationships.

Physical activity and its independent association with clustered cardiovascular risk factors (Andersen *et al.*, 2008) and adiposity (Saelens *et al.*, 2007; Ness *et al.*, 2007) will be discussed further in chapter 2 The measurement of physical activity, the problems and difficulties research groups face in doing so and also the variation in analysis methods must first be understood because they all can lead to confounding and erroneous conclusions regarding physical activity and variables associated with it.

Physical activity measurement can be difficult, particularly in children due the sporadic intermittent and transient nature of children's freely chosen physical activity (Bailey *et al.*, 1995). Within paediatric research a number of methods are used to measure physical activity; ranging from direct objective methods such as calorimetry, heart rate telemetry and **accelerometry** to more subjective measures of 7-day recall and physical activity questionnaires. The more subjective methods such as 7-day recall and PA questionnaires may lack accuracy particularly in children due lower cognitive functioning of children which reduces ability to recall accurately the intensity, frequency and especially duration of activities (Janz, 1995; Sirard, 2001; Mathews, 2002). The accuracy of measurement is imperative in order to provide worthy information about physiological outcomes and benefits. Objective means of assessment such as accelerometry, double-labelled water, heart rate telemetry, and direct observation produce more valid results and can provide additional information regarding the intensity of activity (Riddoch and Boreham, 1995), which is why objective methods are preferred in paediatric research.

Validation studies provide evidence that the accelerometer is an effect tool in measuring activity intensities (Freedson *et al.*, 1998; Trost *et al.*, 1998; Nichols *et al.*, 2000). The increase in the use of accelerometry in the assessment of physical activity over the past few years was highlighted in Rowland's review of physical activity assessment in children (2007), although a recent review of randomised and non-randomised controlled trials highlighted the lack of accelerometer use in paediatric physical activity assessment (van Sluijs *et al.*, 2007). This comprehensive review emphasises the need for objective methods such as accelerometers for physical activity assessment in future research to strengthen current evidence supporting the effectiveness of school-based interventions on............. The need to quantify the type and volume of physical activity required to improve health status was also highlighted as the key conclusion from the review by Molner and Livingstone (2000) of physical activity in relation to overweight and obesity in children.

Accelerometers allow the direct measurement of movement using a mechanism that measures counts per epoch (time interval) to establish duration, frequency and intensity of movement. Movement detected by the motion sensor within the accelerometer is converted into counts depending on the type of movement. The number of counts within a specified time period – an epoch, indicates the intensity of the activity. Therefore time spent in different intensities of activity can be obtained from the accelerometer. This information is ultimately very useful when comparing the data to activity guidelines. Physical activity guidelines for children in the UK stipulate that 60 minutes of moderate to vigorous activity should be achieved daily. In accelerometer counts, activity intensities are defined by count thresholds, but within the current literature there are a number of different thresholds present for each activity intensity (Nilsson *et al.*, 2002; Treuth *et al.*, 2004; Freedson *et al.*, 2005). This discrepancy regarding cut-point thresholds means that the comparitability between studies is limited (Rowlands, 2007). Accelerometers can only measure dynamic work, therefore work such as cycling may not be detected accurately by the accelerometer (Trueth *et al.*, 2004). The fact that accelerometers only measure movement, not energy expenditure is another limiting factor. Energy expenditure can differ between individuals particularly if there is a considerable difference in body mass, therefore comparing obese and non-obese children for example would be inappropriate. Energy expenditure can be assessed thought the double-labelled water method where water labelled with isotope ($^2H_2{}^{18}O$) is ingested, then passed and analysed, but this is expensive, invasive for children and it does not measure intensity of activity.

2.1.4 Summary

In light of the current health status of children discussed in section 1, and the background knowledge of technical assessment supplied in this section, sufficient information has been provided to formulate a rationale for this thesis. Health risk factors including bone fragility and obesity-related diseases are associated with physical inactivity. Epidemiological data suggest that such diseases remain a major health concern in the UK and worldwide. Intervention research is required to investigate the type of activity programme that best improves body composition and fitness. The following sections will provide a comprehensive review of the current literature surrounding these areas, from which the aims and hypotheses will be drawn.

2.2. Bone health and its importance in childhood

From a preventative medicine perspective, maximising bone mass and bone mineral during skeletal growth is essential. Childhood is thought to be the most opportune time to improve bone health. It is thought by many researchers that between 35% - 50% of adult bone mineral content can be accumulated during the pubertal years, with 26% of adult bone mineral accrued over 2 critical years during this period (McKay *et al.*, 2002., Bailey *et al.*, 1999., 1997., Gordon *et al.*, 1991). Bone adapts through a remodelling process at a greater rate in an immature (child) skeleton than a mature one (Parfitt, 1994). Bone mass is enhanced through remodelling mechanisms; including physical activity and appropriate diet; causing the skeleton to become stronger and less susceptible to fracture.

2.2.1 Peak bone mass and the determinants of peak bone mass

During growth, bone mineral density increases until peak bone mass is achieved. Once peak bone mass is achieved, bone mass slowly declines with age. A high peak bone mass achieved during childhood provides a greater reserve for later in life (Van der Sluis *et al.*, 2002); attenuating the effect or incidence of the development of osteoporosis (Ondrak *et al.*, (2007). Thus, preventing osteoporosis begins with maximising bone mineral accrual before adulthood during the opportune time of puberty. It is believed that increased bone mineralisation from weight-bearing exercise before puberty is maintained into adulthood and may reduce the facture risk in later life (Bass *et al.*, 1998; Janz *et al.*, 2004; Vicente-Rodriguez *et al.*, 2006).

Variances in skeletal development are influenced by many factors, genetic, hormonal and environmental influences. The contribution of genetics in determining the variance in BMD ranges from 34% - 85% from various family and twin studies (Gueguen *et al.*, 1995; Nordstrom and Lorentzon, 1999, Patel *et al.*, 2000), but it is still thought to be the most important factor (Khan *et al.*, 2001). The endocrine system contributes to bone acquisition and peak bone mass (Kemper *et al*, 2000) as do environmental factors such as diet and physical activity and are termed modifiable lifestyle factors. Some studies have found that calcium supplementation to significantly enhance bone mineral accrual (Moyer-Mileur *et al.*, 2003; Lambert *et al.*, 2008) but its effects are short lived on follow-up (Khan *et al.*, 2001; Lambert *et al.*, 2008), whilst Ward *et al.* (2007) found no benefit gained from additional calcium supplementation intake in UK 8-11 year old children. Mechanical loading induced by physical activity influences bone mineral accrual through gravitational and contractile forces that places strain on the bone at the muscle attachment (French *et al.*, 2000; Janz *et al.*, 2004). No relationship between calcium intake and bone mineral was found over a 6-year longitudinal bone study (Bailey *et al.*, 2000) which implies that other than genetic and hormonal influences on bone mineral, mechanical stimuli such as weight bearing physical activity may be most beneficial. The focus of this thesis is the effect of physical activity on bone health in children as promoting increases in physical activity, particularly weight-bearing physical activity is one the most achievable from a public health point of view.

Low physical activity is reported as an independent risk factor for low BMD in old women (Pongchaiyakul *et al.*, 2004; Davine *et al.*, 2004; Mavroeidi *et al.*, 2008), thus the adoption of an active lifestyle and participation in weight-bearing activities and exercise in youth can encourage positive changes in bone health and promote increased bone mass and also participation in PA as a lifestyle choice. The extent to how much physical activity and what type of activity should be prescribed to reduce incidence of fracture in later life however, remains largely unclear. There is evidence that supports the preventative effect of high mechanical stimulation during puberty (Kahn *et al.*, 1998., Bass *et al.*, 1998) where children have undergone structured training regimes of high-impact/load bearing for a number of years. This research also confirms that there is little evidence of bone mineral depletion in adulthood due to intensive loading training during childhood and puberty. Although this research is informative, it involves sport-specific populations and therefore cannot be generalised and it is retrospective from which causal conclusions can not be drawn.

2.2.2 Growth and maturation

Puberty plays a key role skeletal growth and development. Maturity status affects bone mineral accrual due to the secretion of hormones that positively affect bone such as oestrogens, androgens and insulin-like growth factor. There is a marked difference in timing of puberty between girls and boys which must be addressed in paediatric research. The pubertal growth spurt of girls occurs 1-2 years before boys (Tanner *et al.*, 1978). Prior to puberty no sex differences have been found in bone mineral content (Molgaard *et al.*, 1997; Ferreti *et al.*, 1998; Maynard *et al.*, 1998). It is suggested that sex differences are more apparent after 14 years of age in bone mineral content (Ferreti *et al.*, 1998) and bone mass development of the whole-body and loading sites (Zanchetta *et al.*, 1995). In both studies, males tend to have larger increases in bone mineral, size and cortical thickness than females. Bonjour *et al* (1995) believed this to be due to a more prolonged bone maturation period in males.

Previous studies (Molgaard *et al.*, Ferreti *et al.*, Maynard *et al.*, Zanchette *et al.*,1995), assessed sex differences using chronological age, and seemingly no sex differences were found for before 11 years but were reported after 14 years of age. As the timing and tempo of maturation varies greatly between individuals of the same sex and between sexes, the use of chronological age when assessing sex differences in bone may be contentious and biological age may be more appropriate. A common measure of biological age is peak height velocity (PHV), described as the age at which maximum linear growth occurs during puberty, which is approximately 8 months prior to peak bone growth. Longitudinal analysis of children aged 8-15 years to investigate independent effect of sex on bone mineral accrual revealed differences (Baxtor-Jones *et al.*, 2003). Males displayed superior accrual at whole body and the femoral neck region at all maturity levels when biological age, body size and composition were controlled (Baxtor-Jones *et al.*, 2003). The authors concluded that the sex differences may be due to taller stature and greater lean mass at each biological age (Baxtor-Jones *et al.*, 2003)

MacKelvie and colleagues (2002) proposed a critical window of opportunity for achieving optimum bone health through exercise during the developmental stages, particularly highlighting early puberty (Figure 2.1); the authors equated early puberty to Tanner stage I-II (Tanner, 1978). Bass and colleagues (1998) agreed that such an opportunity for maximising bone development exists, but believed it to be during pre-pubertal stages, due to the high concentrations of growth hormone present and believe bone mineralisation from weight-bearing exercise before puberty is maintained into adulthood and can offer reduced risk of fracture in later life. Longitudinal research suggests that active children are able to accrue between 10-40% increases in bone mass in the 2 years surrounding peak bone velocity than other less active peers (Bailey *et al.*, 1999).

Peak bone velocity describes the fastest rate of bone growth during puberty and normally occurs close to menarche in girls (~13-14 years old) and about 1.5 years later in boys (MacKelvie *et al*, 2002). Longitudinal findings (Bailey *et al.*, 1999) support MacKelvi*e and colleagues'* (2002) early pubertal suggestion, but at present there is insufficient evidence to support or refute whether bone mass can be maximised optimally during pre (Bass *et al.*, 1998) or early puberty (MacKelvie *et al.*, 2002).

Heineonen *et al.* (2000) highlighted the importance of pre-puberty and early puberty in bone mineral accrual by assessing accrual during the pre-menarchal years. Heineonen *et al.* (2000) assessed the effect of weight-bearing exercise on pre-menarcheal and post-menarcheal girls at lumbar and femoral neck regions. Bone mineral content increased significantly in pre-marcheal girls over 9 months, with no significant effect on post-menarcheal girls. The authors concluded that weight-bearing exercise before menarche may be extremely beneficial to bone acquisition and therefore support both suggestions from Bass *et al* (1998) and MacKelvie (2002).

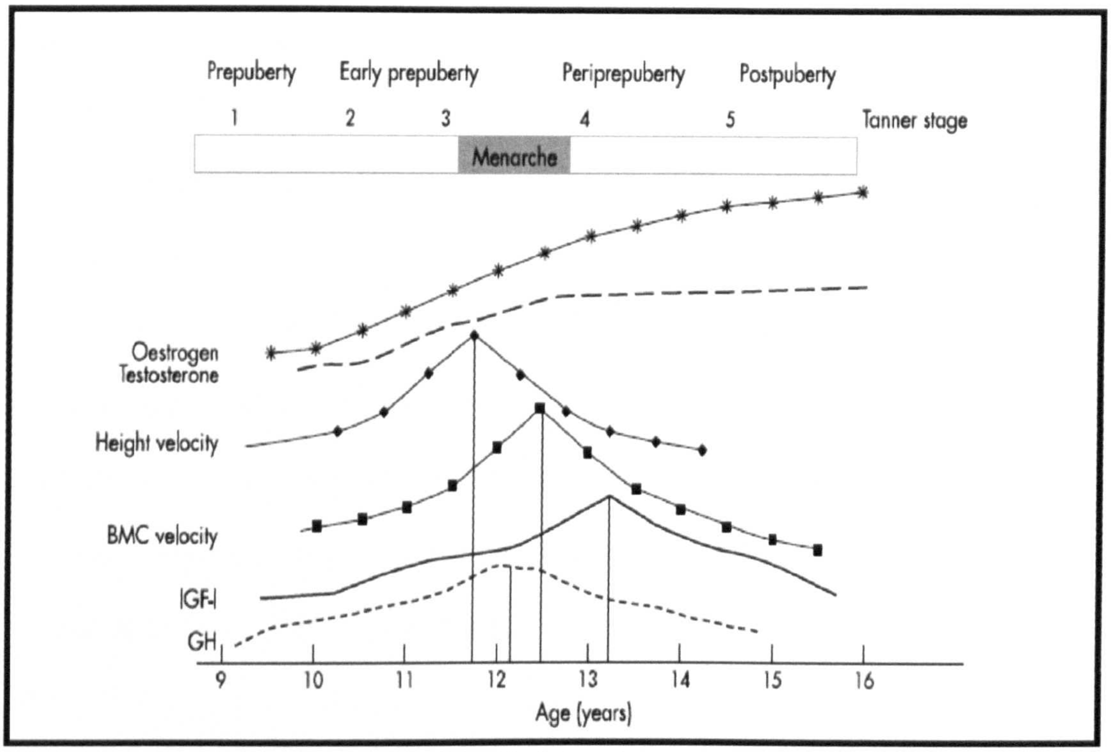


Figure 2.2. MacKelvie *et al*., (2002). Showing peaks for bone velocity (BMC), height velocity, growth hormone (GH), insulin-like growth factor (IGF-I) and oestrogen and testosterone levels relative to age and Tanner stage.

2.3 Obesity and its origins in childhood

The prevalence of overweight and obese children in the UK (DoH, 2005) is rising year by year. The Department of Health (2007) recently described the prevalence of obesity in adults and children as an area of major health concern. Regionally, the North West of England is within the top 5 regions for obesity in children (DoH, 2007) and in Liverpool, over one-third of children aged 9-10 years are classified as overweight or obese (Stratton *et al*., 2007), The suggested relationship between childhood and adult health and behaviour (Blair, 1989) warrants a major public health concern. Government strategies have been put in place across the UK with the aim to halt this rise in obesity and obesity-related diseases.

High levels of body fat have been positively associated with cardiovascular risk factors (Gutin and Owens, 1999) and therefore increase the incidence of illness and premature mortality. The Bogalusa Heart study assessed over ten thousand children; seventy percent of children with BMI≥95th had one risk factor and thirty-nine percent of children showed signs of 2 of the 6 risk factors assessed (Freedman *et al.*, 2007). The aetiology of obesity is a contentious issue and fuels much of the research effort which aims to reduce the prevalence of obesity on a large scale (PSA 12. To reduce obesity in 11 year olds to year 2000 levels by 2020)

2.3.1 Determinants of obesity

The greatest impact on fatness in individuals free from metabolic disorders appears to be diet (energy intake) and physical activity (energy expenditure). Participation in regular physical activity increases energy expenditure therefore promotes healthy energy balance, which can be protective against unhealthy gains in weight and fatness. Accumulation of fat is essentially a consequence of high levels of energy intake and low levels of energy expenditure which is termed as positive energy balance and is when excess fat is stored. The human body's response to sustained high energy intake can be detrimental to health, by increasing the risk of obesity-related diseases.

The endocrine system is thought to play a role in obesity, particularly appetite regulation and energy intake response, but much of this work is still under investigation. The protein hormone leptin is a biomarker for body fat and is thought to have an effect on long-term control of energy intake as it regulates appetite and energy balance. Further, ghrelin and insulin are thought to have a short-term effect on energy intake (Wilbourne *et al.*, 2005). Leptin is produced by adipose tissue and is circulated in plasma signalling energy storage to the brain. Leptin concentrations have been positively correlated to percentage body fat and BMI in children (Valle *et a.l*, 2003., Duley *et al.*, 2007). Ghrelin is a peptide hormone found in high concentrations in the stomach, it is also directly involved with the regulation of energy balance and is linked to obesity (Wilbourne *et al.*, 2005; Da Mota and Zanesco, 2007). Leptin and Ghrelin concentrations can be assessed through blood sampling.

Obese populations have been found to have high concentrations of circulating leptin, this is thought to cause leptin resistance which is suggested to be a component of metabolic syndrome. Leptin resistance can therefore cause energy intake to increase due to irregular appetite signals being sent from the brain. Sustained high plasma concentrations of leptin can cause this desensitisation of cells that respond to appetite. The relationship between energy intake and physical activity (expenditure) mentioned earlier is plausible, but from an endocrinology point of view the relationship between physical activity and concentrations of circulating leptin and ghrelin remains unclear (Da Mota and Zanesco, 2007).

Ideally participation in regular physical activity combined with adequate food intake maintains a healthy energy balance and off-sets trends towards overweight and obesity. Paediatric research found that obese children with improved levels of physical activity were found to reduce percent body fat, with or without a calorie-controlled diet (Bar-Or, 1994). Such evidence suggests physical activity to be the primary modifiable lifestyle factor for health benefits. Supporting literature also correlates low fitness cardio-vascular disease and body fat (Ara *et al.*, 2004., Eiberg *et al.*, 2005); there is however strong evidence to suggest that diet plays a more dominant role (Capewell *et al.*, 2004). Prentice and Jebb (1995) extensively reviewed British epidemiological data highlighting the development of obesity and the increase of inactivity and energy intake. The authors believed that physical activity plays a valuable role in reducing obesity and should be considered as important as diet in public health strategies.

2.4. Musculoskeletal development and bone mineral accrual.

Mechanically, physical activity has an effect on bone through stress and forces from movement. Tobias *et al.* (2007) highlighted the indirect effect body composition has on bone mineral from physical activity. Both lean mass and fat mass can play a role in bone mass through bone mineral accrual. Lean mass (muscle) places contractile forces on bone from during movement causing stress and promotes remodelling. When lean mass is increased through physical activity or exercise; bone mineral is consequently enhanced indirectly. The muscle-bone unit (Frost and Schonau, 2000; Rauch *et al.*, 2004) theory also stipulate that the contractile forces placed on the bone in activities such as weight-training are comparable to loco-motor activities such as running (Snow-Harter *et al.*, 1992) in adult females. Given the additional cardiovascular benefits obtained from activities such as running, participation is weight-bearing activities like sport will have a greater osteogenic influence compared to non-weight-bearing activities (Vicente-Rodriguez *et al.*, 2004) and may also have additional benefits.

Lean mass is reported to be the strongest determinant of total-body bone mineral content, with fat mass and body mass contributory predictors to a lesser extent (Pietrobelli *et al.,* 2002). During the pubertal years lean mass has been reported to be the only variable to explain the gender related difference in bone mineral content (Ferreti *et al.*, 1998). Lean mass was also found to be a better predictor of femoral BMC and BMD in pre-pubertal 9-year old children (Vicente-Rodriguz, 2005). A strong relationship between BMC and lean mass was also reported in healthy school children (Crabtree *et al.*, 2004), supporting mechanisms of mechanostat theory. Uusi-Rasi *et al.* (1997) reported body mass as the most important determinant of BMC and BMD in children, with impact exercise during pubertal years beneficially affecting skeletal loading sites, such as femoral BMD. This finding may imply that obese children have healthier bones due to increased mass (largely body fat mass) placed upon them. This interpretation was contested by negative relationship between percentage of body fat and bone mass (Weiler *et al.* 2002), where the authors proposed that younger children may experience suboptimal bone mass because of this. Weiler *et al.* (2002) further suggested that high body fat relative to weight did not support the attainment of optimal peak bone mass, a notion that is also supported by the muscle-bone unit theory that states that it is the contractile forces placed on the bone by the muscle that stimulates bone accrual. It is clear that weight-bearing physical activity performed at an intensity and volume sufficient to promote bone mineral accrual, increases lean mass and reduce body fat is key. This close connection of physical activity to both body composition and bone development will be the foci of this thesis.

2.5 Physical activity in children

The abundant health benefits gained from physical activity have been previously acknowledged. There is evidence that children are not meeting the current physical activity (PA) guidelines (60 min.day^{-1}) and are therefore participating in insufficient physical activity to yield health benefits (Riddoch *et al.*, 2007, Mattocks *et al.*, 2008). Unfortunately the quality of research within this area of physical activity assessment is diverse, and many studies are criticised on assessment methods. The increased use of objective means of physical activity measurement such as accelerometry in paediatric research is commendable; however common use of 1-min epoch settings to accurately measure physical activity is children (Ruiz *et al.*, 2006; Andersen *et al.*, 2006; Hussey *et al.*, 2007; Rowlands *et al.*, 2007) may be questionable and inappropriate.

The Avon Longitudinal Study of Parents And Children study (Riddoch *et al.*, 2007) provides an example of the possible misinterpretation of physical activity reports when 1-min epoch are used to record physical activity. In a large study that used accelerometry to measure physical activity British children aged 11 years old were insufficiently active. Only 2.5% of children met current activity guidelines for health of 60 min.day^{-1}. The mean time spent in moderate to vigorous physical activity (MVPA) was 20 minutes per day, but given that accelerometers were programmed to record physical activity counts in 1-minute epochs, it is not surprising that the time reported in physical activity is small. The sporadic, unstructured nature of children's physical activity may in fact be unrecognised within this 1-minute interval setting, the use of a shorter time interval e.g. 5 sec epoch, may have been more sensitive.

Dencker *et al.*, (2006) utilised a 10-sec epoch setting to assessing vigorous physical activity. The count per minute thresholds (>583 cpm/10s epoch) when equated to 1-min (583 x 6 = 3498cpm) epochs were similar to the 1-min epoch thresholds (>3500 cpm) for vigorous activity used by other authors (Ruiz *et al.*, 2006; Hussey *et al.*, 2007). But were greater than the vigorous thresholds used by Trueth *et al.* (≥2200) and less than those set by Puyau *et al.* (2002) or >8200 cpm.

A 1-minute epoch duration may be suitable and appropriate for more structured physical activity behaviour typical of adults, but may not be sensitive enough to accurately account for children's vigorous activity and therefore it is possible that vigorous activity could be underestimated using epochs > 5 seconds (Baquet *et al*, 2007). Therefore all 1-min epoch data discussed with reference to time spent in vigorous activity should be viewed with caution.

It was been acknowledged by many that the ideal environment to effectively promote physical activity is at school (Calvill *et al.*, 2001, McKenzie, 2001). Furthermore, with the year-on year rise of children classified as obese (DoH, 2005) and the well-documented relationship between physical activity and body fatness, the promotion of health and physical activity schemes within schools is necessary. Children spend a large proportion of their day at school. Further a health education infrastructure exists through the formal curriculum making it an ideal environment to administer health-promoting schemes.

2.6 Bone health research in children

There is a common consensus that a positive association between mechanical loading (physical activity) on bone mineral content and bone mineral density in children exists. One of the main aims of bone research in exercise science is to establish if participation in physical activity (structured or unstructured) or sport enhances normal bone development during growth. School cohorts are commonly used in bone related paediatric research (Gutin *et al.*, 1999; Fuchs *et al.*, 2001; MacKelvie *et al.*, 2003) as are trained sports populations (Scarpella *et al.*, 2003; Greene *et al.*, 2005). Much of this research is limited by cross-sectional studies that, despite finding significant relationships between bone and physical activity, do not provide solid evidence of a causal relationship. Intervention studies carried out within this area often differ greatly in design and methodological aspects, making it difficult to draw firm conclusions as to the best programme for bone accrual., there are also a limited number of studies that track children's bone growth longitudinally due to logistical and practical constraints (Bailey *et al*, 1999; Janz *et al.*, 2006).

In a 6-year longitudinal study, Bailey *et al.* (1999) explored the relationship between habitual physical activity and peak bone mineral accrual, and indicated that peak bone mineral accrual could be maximised by high levels of activity during childhood. Another large longitudinal study also established that a high level of habitual activity was associated with optimal increases in total body and trochanter BMC in both boys and girls (Janz *et al.*, 2006). Cross-sectional studies generally indicate that children who were habitually more active possessed greater BMD than inactive children (Scarpella *et al.*, 2003; Janz *et al.*, 2004). However unlike longitudinal designs, cross-sectional research is not effective at controlling for genetic bone pre-disposition and therefore relationships must be acknowledged with caution. Cross-sectional bone research within child populations has suggested a dose-dependant relationship between time spent in physical activity and bone mineral accrual in gymnasts (Scarpella *et al.*, 2003.; Ward *et al.*, 2005), game players (Vicente- Rodriguez *et al.*, 2004) and athletes. Furthermore, the duration and intensity (low, moderate, vigorous) of activity is often assessed through accelerometry which gives a useful insight into bone loading (mechanical stimulation) and enhancement of bone in related research providing the correct epoch is used.

A recent Danish study with 6-8 years-old children indicated total time-spent in habitual physical activity and time spent in vigorous-intensity activity were significantly related to calcaneal and forearm BMD (Hasselstrom *et al*, 2007).

The authors also analysed the data using a range of vigorous intensity cut-points, all intensities were significant, which makes it difficult to conclude what level of activity is the most beneficial to BMD development, if any. Interestingly, the loading (calcaneus) and a predominantly non-loading (distal forearm) site were both significantly correlated with time spent in total and vigorous activity. Physical activity was assessed using an accelerometer (worn on waist) on a 10-second epoch setting, providing more accurate data than the commonly used 1-min epoch setting abundant in the literature. The findings could suggest that loading activity (play) has increased BMD at non-loading sites.

Time spent in high impact activities such as jogging, tennis, football, rugby and basketball was positively associated with whole body and hip BMC in adolescent boys (Ginty *et al.*, 2005), but the accuracy of the physical activity data is questionable because it was derived from questionnaires, limiting the validity of the research. A positive relationship was also found between accelerometer measured moderate to vigorous physical activity (MVPA) and lower-limb BMD in recent study of a English children (Tobias *et al.*, 2007). The authors also found that moderate activity exerted the strongest influence on lower limb BMC. Methodologically, the measurement of physical activity intensity was over 1-minute epochs, which may not accurately account for levels of vigorous activity in children.

A recent review of 22-randomised controlled trials (Hind and Burrows, 2007) supports the importance of weight-bearing exercise but concluded that an optimal programme to enhance bone mineral accrual remains unclear. Many training programmes within this research area differ in volume and intensity level. Some of the intervention programmes facilitated in the school environment have focused on mechanical loading action of jumping (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; 2002; McKay *et al.*, 2005; Weeks *et al.*, 2008). The majority of which, focus on bone mineral changes in the site specific femoral neck and lumbar spine region (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; 2002; McKay *et al.*, 2005). A reason for this is that these sites consist largely of trabecular bone which is very responsive to changes in mechanical load (Heinonen *et al.*, 2000; Fuchs *et al.*, 2001) and therefore enhance bone local to those sites. Few of these jump-based intervention studies (Weeks *et al.*, 2008) give evidence of increases in total body BMC or BMD. Participation in general high-impact weight-bearing physical activities such as sports or games has shown through cross-sectional data to have a similar effect on bone to jump based exercises, but there is limited evidence (Linden *et al.*, 2006) that general weight-bearing physical activity (not specifically jump-based) could induce an overall total bone mineral increase

MacKelvie *et al.* (2001a, 2003) conducted a 2 year (20 months) programme of progressive high-impact, jumping-based circuit exercises. During the first 7-months (MacKelvie *et al.*, 2001a) significant increases in BMC in femoral neck and lumbar spine regions were observed by early pubertal girls (Tanner 2-3) and boys (MacKelvie *et al.*, 2004) compared to maturity matched controls, but no significant changes in total body bone measures. No significant changes in pre-pubertal girls (Tanner 1) were reported for total body or site specific BMC or BMD after first 7 months. Significant increases in BMC of femoral neck and lumbar spine regions were also found compared to controls after 20 months of the same jumping-based circuit programme (MacKelvie *et al.*, 2003). The intervention however was only implemented for 14 out of the 20 months, the programme had a 6 month break in the middle, but only baseline and post intervention measures were taken. A significant amount of detraining could have occurred within this 6 month period which may have dampened the findings, despite this, significant changes in femoral neck and lumbar spine regions were recorded, but no significant changes were found in total body bone mineral. Measurements taken at the end of the first 7 months and the beginning on the second 7 months would have provided more comprehensive data.

Another 7-month randomised controlled intervention (Fuchs *et al.*, 2001) reported similar findings. A mixed group of 89 girls and boys aged 6-10 years performed 2-footed jumps off a box (Ground Reaction Force of ~8*body mass), 100 times, three sessions per week. The jumping group had significantly greater increases in BMC and BMD of lumbar spine and BMC of femoral neck region compare to controls that performed non-impact stretching, total body bone mineral was not measured. Increased BMD of hip region in 10-year old children was also reported from an 8-month jumping intervention (McKay *et al.*, 2005). Ten counter-movement jumps (GRF of ~5*body mass) were performed 3 times per day (~3 min/day) in addition to curriculum physical education. Significant increases of BMC of proximal femur (2%) and the inter-trochanter (27%) were found compared to the control group, but no significant changes at the femoral neck, the study also found that positive total body BMC changes were only evident in the control group who performed mandatory physical education classes during school time. Heinonen *et al*, (2000) integrated a 20-minute high-impact jumping component into a 50-minute aerobic training session, consisting of a progressive programme of 100 to 150 both-leg and single led jumps each session. Training sessions were performed twice weekly over 9-months. In pre-menarchael girls, substantial increases in BMC of lumbar spine and femoral neck were found compared to maturity matched control girls. No significant changes were evident in post-menarchael girls between groups although, no total body bone measures were reported. Total body BMC gains were acknowledged, however, in 13-year old children in a recent study that also integrated10 minutes jumping activity into a general PE lesson (2 x week) for 8 months (Weeks *et al.*, 2008). This was one of the few studies that attempts to improve skeletal health through more practical application and a programme (POWER PE) that can be easily integrated into school activity. Weeks *et al* (2008) found the intervention to significantly increase total body BMC in boys only, although positive changes were observed by girls in femoral neck and lumbar spine regions, differences were not significant.

Linden *et al.* (2006) assessed total body bone mineral along with lumbar spine and femoral neck regions in girls (7-9 years old). The 2 study modified the duration of school-time physical activity (variety of games, running, jumping and climbing) of moderate intensity, it was increased from 60 min/week to 200 min/week through the school curriculum. Age-matched controls continued to participate in 60 min/week. Significant increases of total body and lumbar spine BMD and also lumbar spine BMC were evident in children performing 200 min/week of school-time physical activity at moderate intensity. The findings suggest that by increasing time spent in physical activity within the school structured environment can have a positive effect on bone mineral accrual in total body and lumbar spine regions. No significant changes were reported for femoral neck bone mineral, although bone size did change significantly over time, which could support the relationship between bone and physical activity. It could be suggested that the general activity programme provided insufficient loading to stimulate site specific femoral neck bone mineral changes and the nature of the general play-like activity did not allow ground reaction forces to be achieved. The design of this study was not randomised, largely due to the cohort and the nature of the study, the intervention was implemented in one school, with three other schools serving as controls. If the intensity of the PE lessons was assessed in this study, it could have provided a bench mark for activity intensity that served to elicit bone mineral changes.

The intervention trials discussed ranged from very structured jump-based programmes (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; McKay *et al.*, 2005) to more integrated programmes of general aerobic training and school curriculum PE lessons (Heinonen *et al.*, 2000; Linden *et al.*, 2006; Weeks *et al.*, 2008). All of which have been successful in improving BMC or BMD in total body or site specific regions or both. The jump-based structured studies, in particular Fuchs *et al.* (2001) 100 counter movement jumps, 3 x week, and McKay *et al.* (2005) ten counter-movement jumps, 3 x day, 5 days a week, and Heinonen *et al.* (2000) progressive jump programme would be difficult to implement in practical situations. It appears that similar benefits can be gained from increased frequency or duration of an existing loading activity such as children's play/sports activities similar to those performed in PE activities (Linden *et al.*, 2006). Such activities would require less external motivation, may be more sustainable, easier to implement and would increase the ecological validity of the intervention.

Dose-dependant findings among sporting populations (Scarpella *et al.*, 2003, Vicente-Rodriquez *et al* 2004., Greene *et al.*, 2005) support the use of physical activity intervention programmes aimed at enhancing bone mineral. Many research groups have attempted to quantify the dose of physical activity required to elicit positive bone mineral accrual. Intensity has already been established as an influential factor. Physical activity intensity is determined by accelerometry data using thresholds, intensity can also be expressed in heart rate (bpm) by use of heart rate monitoring systems or estimated through questionnaires. Both volume and intensity are useful when reviewing intervention studies to highlight differences in the programmes prescribed and also to explore the main determinant of bone mineral accrual in children

Within sporting populations, significant bone mineral accrual was reported in pre-pubertal children performing 3 hours/week of football (Vicente-Rodriguez *et al.*, 2004). Research illustrated that young gymnasts who train over 8 hours/week had significantly greater total and forearm BMD that gymnasts that train for less than 8 hours/week (Scarpella *et al.*, 2003). A retrospective study with retired gymnasts considered osteogenic benefits gained from high training volumes before puberty as having a beneficial effect on reducing fracture risk (Bass *et al.*, 2004). In a large population based cohort of children, Tobias *et al.* (2007) found moderate activity to have the greatest dose response association with lower body BMD, compared to light and vigorous activity using 1-min epochs in accelerometer assessment. It is however possible that vigorous activity may have been underestimated.

Linden *et al.*, (2006) suggested that time-spent, rather than type of physical activity was more influential on bone; when reporting increased lumbar spine BMC and total body BMD through increasing school-time general physical activity from 60 min/week to 200 min/week, equating to 40 min per day, although the intensity of lessons was not reported. The limitations surrounding the non-randomised design however make it difficult to confirm this suggestion. Jump-based interventions (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; McKay *et al.*, 2005) highlighted previously report significant bone mineral changes from medium intervention duration (~7 months) with a small session duration (or dose) of loading activity (<10 minutes). This suggests that this combination of short session duration with medium intervention duration may contribute to only regional improvements of bone measures reported (Fuchs *et al.*, 2001;

MacKelvie *et al*; 2001, 2002; McKay *et al.*, 2005), which could suggest that a longer intervention period or a longer session duration or both is required to elicit total body bone mineral changes as found by Linden *et al* (2006). Significant improvements in total body BMC and BMD were evident from a shorter 4-month multi-activity intervention (Barbeau *et al.*, 1999, Gutin *et al.*, 1999) with longer sessions (40 min). Regression analysis from this study also highlights that a higher frequency in attendance (4 x week) and time spent in more vigorous activity were associated with greater changes (Barbeau *et al.*, 1999).

Intervention studies that prescribe specific mechanical movements such as jumping (Fuchs *et al.*, 2001; MacKelvie *et al*; 2001, 2002; McKay *et al.*, 2005) to elicit bone mineral accrual may be criticised for the almost military structured nature of the intervention, given the paediatric population. Such interventions over several months and years may not be attractive to children, and their motivation and overall enjoyment may be questionable. Attrition for such studies, however, is low; it may be that the school-based nature of the interventions that occur during school time and not after school, encourages retention. In contrast, the inclusion of jumping, hopping, running and skipping into curriculum-like activities and games (Barbeau *et al.*, 1999, Gutin *et al.*, 1999; Linden *et al.*, 2006) may be more sustainable from a motivational point of view, regardless of whether they are performed during or after school time. Obese children who performed a combination of exercise machine activities (rowing, cycling) and vigorous games activities for 40 minutes, 4 times per week for 4 months benefited from significant increases in total body BMD and BMC compared to obese controls (Barbeau *et al.*, 1999). The cross-over design of the intervention allowed bone mineral to be monitored after intervention cessation, for 4 months. Findings showed that BMC and BMD increased more during periods of training than non-training (Gutin *et al.*, 1999).

The variability of programmes with the discussed research makes it difficult to prescribe a minimum level activity to stimulate increases in bone mineral accrual above the normal growth rate. The intervention studies mentioned reinforce the importance of impact activity on bone remodelling. Jump-based interventions may be simple and time and cost effective but participation and motivation of children may be compromised, therefore activities that combine short-intense bouts of jumping, skipping, running within games may be more effective in stimulating beneficial changes in a young skeleton, and may also have a positive effect on physical activity behaviour and future health.

2.7 Body composition interventions

It is well documented that increased physical activity levels have a positive effect on body composition, namely increasing lean tissue mass, decreasing fat mass and percent total-body fat. Cross-sectional studies indicate that children who were more active and had lower body fat (Abbot and Davies, 2004; Saelens *et al.*, 2007; Ness *et al.*, 2007) than less active counterparts. Total daily physical activity has also been negatively related to visceral abdominal fat in children (Janz *et al.*, 2006; Saelens *et al.*, 2007), and following regression analysis, total body fat and physical activity measured by accelerometry accounted for 93% of variance in visceral adipose tissue

(Saelens *et al*, 2007). In addition to total physical activity, cross-sectional research has uncovered relationships between the intensity and volume of activity and its effect on body composition.

Current children's activity guidelines of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day are associated with health benefits and risk prevention. The European Youth Heart Study (Andersen *et al.*, 2006) assessed habitual activity (accelerometry) and clustered (including body fat) cardiovascular risk. Only children in the top 2 quintiles for physical activity were void of any raised cardiovascular risk. Children in the top 2 quintiles participated in 116 min per day in moderate activity. Andersen *et al.* (2006) concluded that current guidelines of 60 min per day of moderate intensity activity provide an insufficient volume to prevent risk factors appearing in children and suggested the guideline should be increased to 90 min per day of moderate to vigorous activity. A positive association between fatness and physical activity (Duncan *et al.*, 2006) was reported by pedometer research in New Zealand school children; overweight (including obese) children participated in significantly less physical activity than non-overweight counterparts. Further work by Duncan *et al.* (2008) also confirmed low physical activity as an independent risk factor for excess body fat. An inverse relationship between structured physical activity and waist circumference in 12-year old children was also found by Klein-Platat *et al.*, 2005), demonstrating the positive effect of structured physical activity has on abdominal adiposity and subsequent cardiovascular risk. Specific time thresholds for such benefits, however, were not deduced.

With reference to activity intensity, Ruiz *et al.* (2006) found an association between lower levels of body fat and higher levels of vigorous physical activity in the EYHS data; children who engaged in >40 min of vigorous physical activity each day had significantly lower body fat than those participating in 10-18 minutes each day. The European Youth Heart Study also showed children (9-years) and adolescents (15-years) who participated in less vigorous activity were more likely to be overweight or obese and to have a high-risk waist circumference than those who participate in greater amounts of vigorous activity (Ortega *et al.*, 2007a). The physical activity intensity was assessed directly through accelerometry, over 1-minute epochs. Increased total body fatness was also found to be significantly associated with low levels of vigorous activity in another longitudinal study, but not with moderate activity (Janz *et al.*, 2002). Abbott and Davies (2004) assessed the activity intensity and the time spent in physical activity of Australian children aged 5-10 year old through 1-minute epoch accelerometry. Children who spent more than 125 $min.day^{-1}$ in "*vigorous*" activity (2000-3499 cpm) had significantly lower percent body fat, than children who spent less than 125 $min.day^{-1}$ in *vigorous* activity. In addition, children who spend more than 15 $min.day^{-1}$ in "*hard and above*" activity (>3500 cpm) also had significantly lower percent body fat than those who spend less than 15 minutes at this intensity. Moreover, the children in the top tertile for vigorous activity (>125 min) and hard and above activity (>15min) account for one third of the children assessed. This research is limited by the use of 1-min epochs in physical activity assessment, the use of intensity terminology and thresholds (moderate, vigorous and hard and above) also differs from that in previous studies mentioned, which is confusing when comparing studies. Cross-sectional research is also limited to relationships and does not provide causal relationships.

Participation in high-intensity activity rather than moderate or low-intensity activity may therefore be more beneficial in reducing body fat. Activity sessions of vigorous intensity with children performing above 70% of maximal heart rate are likely to have a favourable impact on lean and fat mass and also improve cardiovascular function over time (Gutin *et al.*, 1999, 2002). Activity of vigorous intensity (working at 70% of maximum heart rate) requires more energy, which will in turn affect energy balance, promote lean muscle and reduce body fat. Low-intensity exercise (working at 30% maximum heart rate) of the same volume requires less energy, may not result in any change in energy balance and therefore is insufficient to promote notable positive body composition outcomes.

The method of assessment of body composition variables must be considered when reviewing literature; different methods of assessment were discussed in Chapter 2. Physical activity and exercise-based research programmes that utilise objective methods of assessment have found favourable results; however, programmes may be criticised for using assessment measures such as 1-2 skin-fold thicknesses and/or BMI as a measure of obesity. Self-report techniques for physical activity may also lack accuracy and reliability compared to multi-site skin-fold and densitometry. Unfortunately, all variables are seldom measured objectively in these studies.

A school-based physical activity programme was employed by 9 schools in Switzerland over one academic year (Zahner *et al.*, 2006). The programmed involved a whole-school approach where many activity promoting strategies were inaugurated within the school environment. This multi-component design included; increased physical education classes from 2 to 5 lessons per week, academic lessons were also supplemented with short (2-5 min) activity breaks, physical activity homework was also given for skill improvement, strength and fitness, the school play areas were adapted to encourage activity, active commuting to school was encouraged as was parental support. Body composition was assessed by means of dual energy x-ray absorptiometry (DXA) and by 4-site skin-fold thickness. Significant decreases in body fat (%) were only evident in skin-fold thickness, suggesting that skin-fold changes may not be accurate given the inconsistent relationships between paediatric skin-fold thickness derived body fat and DXA-derived body fat. Increases in total time spent in physical activity through accelerometer assessment were also recognised. The favourable outcomes documented by this large study are encouraging; it may be difficult, however, to decipher which treatment or combination of treatments was most responsible for the results, as the effect of each component was not reported.

Reductions in body fat (assessed by bio-electrical impedance) and triceps skin-fold thickness were found by Martınez Vizcaıno *et al* .(2008) from a 24 week after school physical activity intervention programme which consisted of 3 x 90 min per week incorporating aerobic and muscular strength exercises. Martınez Vizcaıno *et al.* (2008) quantified the intensity of sessions using accelerometers on a random selection of children, the mean count per minute (cpm) per session were 1345.48, with 33.5% of the sessions dedicated to a mean intensity of 1700 cpm; which equates to approximately 30 minutes. Thus, 30 minutes of vigorous activity, 3 times per week had a positive effect on reducing body fat in 9-10 year old children.

There is limited literature available that objectively assesses both physical activity/exercise and body fat in intervention research in all sediatric populations, particularly the non-overweight. There are numerous interventions that explore the effects of exercise programmes on overweight or obese populations (Knopfli *et al.*, 2008; Humphries *et al.*, 2001; Barbeau *et al.*,1999; Gutin *et al.*, 1999 and Owens *et al.*, 1999) and many that use multi-treatment programmes, which rarely investigate the individual effects of each treatment, making it difficult to draw clear conclusions.

Knopfli *et al.* (2008) reported a significant decrease in body fat and increase in fitness following a 8 weeks multi-treatment program, which included a restricted diet, daily PA (2x 60 min per day) and education in severely obese children (aged 12-15 years). The study highlights the effectiveness of the multi-treatment programme, but fails to explore the effectiveness of the PA programme alone, which would have given insight into the effect of the PA training independent of diet and education.

A research group studied obese children (7-11 years old) participating a physical training programme of multi-activity sessions (4x 40 min per week) over 4 months, significant reductions in percent body fat, fat mass, subcutaneous abdominal fat, visceral adipose tissue and increased fat free mas were found (Barbeau *et al.*,1999; Gutin *et al.*, 1999; Owens *et al.*, 1999; Humphries *et al.*, 2001). In a later study, Gutin *et al.* (2002) explored the effect of exercise intensity on body composition. Moderate-intensity and high-intensity training groups of older (13-16 years) obese children performing two or more sessions weekly over 8 months were compared with a non-training group. There was no evidence that high intensity exercise was more effective than moderate intensity activity at reducing body fat. When training groups were combined, a significant positive changes in body composition, total and visceral adiposity were found compared with the non-training group, this could be due to an increase in statistical power. In contrast, a short-term (8-week) progressive exercise regimen combining cycling and resistance training sustained at a moderate-vigorous level for 1 hour per week produced significant increases in total lean mass but no significant decrease in total body fat in obese children and adolescents (Watts *et al.*, 2006). The short duration of the exercise intervention may explain why changes in body fat were not significant; however, it is unclear whether the cycling, resistance training or the combination of both components were responsible for the reported increases in lean tissue mass over such a short period of time.

Favourable body composition outcomes have also been observed in interventions combining exercise programmes with lifestyle education (Gutin *et* *al.*, 2002; McMurray *et al.*, 2002). Gutin *et al.* (2002) ran a lifestyle education alongside the previously mentioned moderate and vigorous training groups. The obese children received either the lifestyle-only treatment consisting of one education session bi-weekly, lifestyle plus moderate intensity physical training (2 x week) or the lifestyle plus vigorous physical training (2 x week) over an 8-month period. Significant decreases in percent body fat and visceral adiposity were found when training group data was combined and compared against lifestyle-only group data. Again, without knowing the independent effect of either moderate or high-intensity physical training it is hard to ascertain the true effect either intensity or the complementary effect of lifestyle education. In a similar study in young adolescents, McMurray *et al.* (2002) assessed education-only, exercise-only and education and exercise treatments combined. The exercise component involved 30 min of aerobic exercise (3 per week) entailing non-competitive games and activities; the education classes included information on health, exercise, smoking and nutrition, which they attended twice weekly. The exercise and education group participated in both. This short-term (8-week) school-based intervention induced significant favourable changes in skin-fold sites. The sum of skin-folds increased less in both exercise intervention groups compared to the control and the group receiving education-only treatment. Despite significant changes in skin-fold thickness after 8 weeks, a longer intervention with a more robust method of body fat assessment may have provided more sensitive measures. Unfortunately intensity of the exercise sessions was not reported.

Intervention studies conclude that sessions of vigorous-intensity activity where children exercise above 70% of maximal heart rate are likely to have a favourable impact on lean and fat mass (Gutin *et al.*, 1999, 2002). Threshold values of time spent in vigorous activity, and the frequency of such bouts have been proposed in the literature, yet an effective dose that elicits such beneficial results remains unclear. The different methodologies for measurement of physical activity, varying cut-point values for intensity of activity and the diverse combination of volume and frequency of physical activity sessions in intervention studies contribute to difficulties in prescribing activity programmes that are effective. Such disparity can make findings difficult to interpret, compare and apply. Moreover, the important information to be taken from all of these previous studies, regardless of the methodological discrepancies discussed, should be the lack of time spent in the upper intensities of physical activity, and how this may contribute to the current health status of children.

2.8 Summary

From the research discussed, few studies have endeavoured to promote the bone mineral accrual and challenge the increase of childhood obesity with interventions that also promote physical activity through exercise/physical activity and lifestyle programmes in the absence of dietary intervention.. This thesis will assess the extent to which structured physical activity and lifestyle-based physical activity affects bone health and body composition and in doing so assess current bone health status physical activity, and body composition status of a sample of Liverpool school children.

Chapter

3

General Methods

3.0 General Methods

The subjects, setting, research design and analyses will be described separately for the exploratory study (Study 1) and the baseline study of examining relationships between physical activity, fitness and body composition (Study 2) and the 12-month intervention study (Study 3) in their respective chapters (4,5 and 6). The common instruments and procedures for all studies will be described in this chapter.

3.1 Instruments and procedures

3.1.1 Data Collection

Laboratory data was collected when children visited the Research Institute laboratories at Liverpool John Moores University. Children attended university laboratories to undergo a series of physiological measures. All children were given information packs to aid understanding with detailed advice on physical activity and health, any further explanation was given verbally. Physical activity data was obtained from visiting children in school to distribute and collect activity monitors.

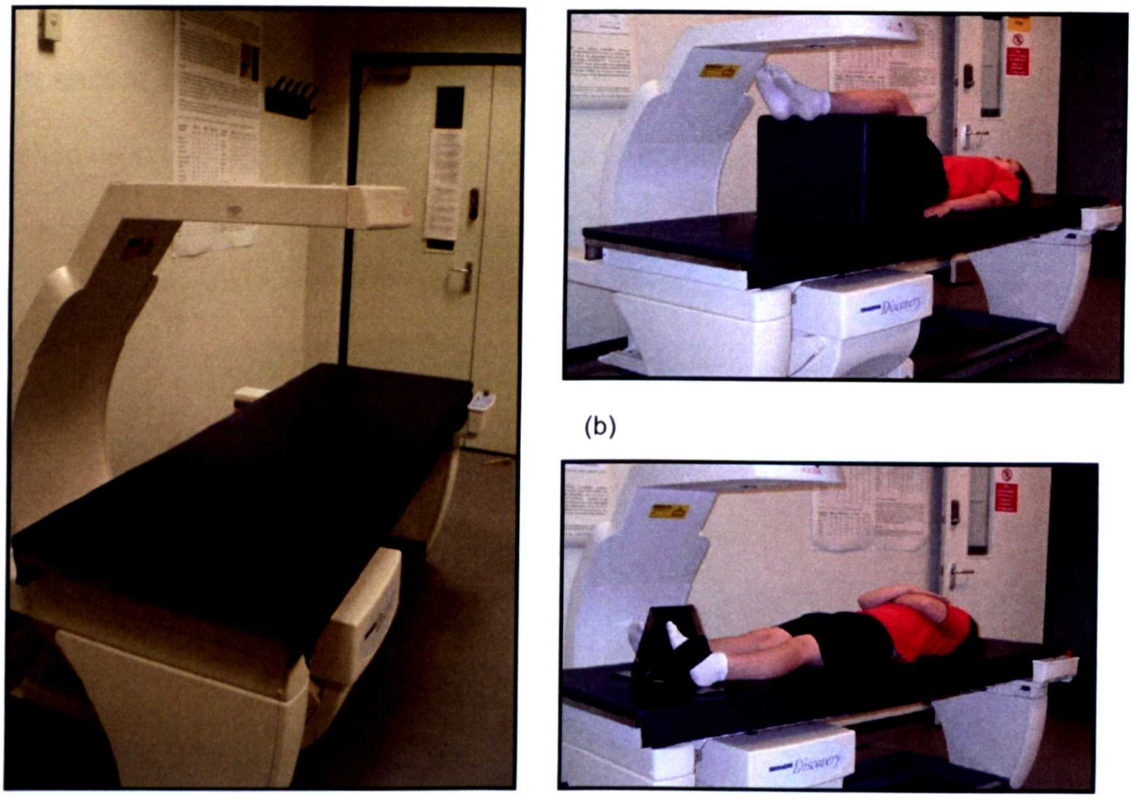
Ethical permission was obtained from the institution's Research Ethics Committee Ethics, clearance number: 05138.

3.1.2 Anthropometry

A researcher trained to standards of the International Society for the Advancement of Kinanthropometry (ISAK) took all anthropometric measurements. Stature and sitting stature were both measured to the nearest 0.1 cm with a Leicester Height Measure (Seca Ltd, Birmingham, UK). Mass was assessed to the nearest 0.1 kg in light clothing without shoes using Seca scales (Seca Ltd, Birmingham, UK). Body Mass Index (BMI) was calculated as mass divided by stature (kg/m^2). Ethnicity was recorded from medical questionnaires completed by parents prior to commencement of study.

3.1.3. Dual-energy X-ray absorptiometry: Bone mineral and Body Composition

Bone mineral content (g) and areal density (g.cm^{-2}) of the total body (TB), femoral neck (FN) and lumbar spine (LS) were determined by means of dual-energy x-ray absorptiometry (DXA: Hologic QDR series Discovery A Fan-beam, Bedford, Massachusetts). Dual-energy X-ray Absorptiometry provides both total body and segmental data on both bone and body composition data. Dual-energy X-ray Absorptiometry is considered the gold standard on bone densitometry (Lewiecki, 2005). Dual-energy X-ray Absorptiometry measures a cross-sectional area of a scan, therefore it should be noted that the BMD scores provided by DXA are estimated from BMC and bone area (BA) as DXA only provides areal BMD volume determinations cannot be made (Khan *et al.*, 2001). Bone mineral content and density were estimated in the L1-L4 (LS) region by the anterior-posterior lumbar spine scan (Figure 3.1b), in the femoral neck (FN) region from the hip (left) scan (Figure 3.1c) and the total body from the total body scan. This order of scans was performed. Lumbar spine and femoral neck scan time was approximately 1 minute, the whole body scan lasted approximately 3 minutes. With allowance for explanation of assessment procedures and out, total time for DXA assessment was approximately 12 minutes for each participant.



(b)

(a)

(c)

Figure 3.1 Dual-energy X-ray absorptiometry scanner (a) patient positioning for lumbar spine scan (b.), patient positioning for femoral neck scan (c.).

The densitometer provided absolute (kg) fat mass (FM) and lean tissue mass (LM) and relative (%) percent body fat (%BF) data from the total body scan (Figure 3.1c). Distribution of body fat mass and lean mass was also achieved through segmental analysis. Regional areas of total arm, total leg and trunk segments were recorded for fat and lean mass and determined by combining the scan output data for each variable i.e. total arm fat = left arm fat + right arm fat).

All scans were completed in accordance with standard operating procedures. Participants were scanned in the supine position and wore lightweight clothing and no shoes (Figure 3.2). All scans were carried out by the same qualified researcher. The scans were analysed after each assessment using Hologic QDR software for Windows version 11.2 (©1986-2001 Hologic Inc.) and stored in secure data files. The researcher discussed the results with the child. Each child received a copy of their DXA output (Appendix A:1).

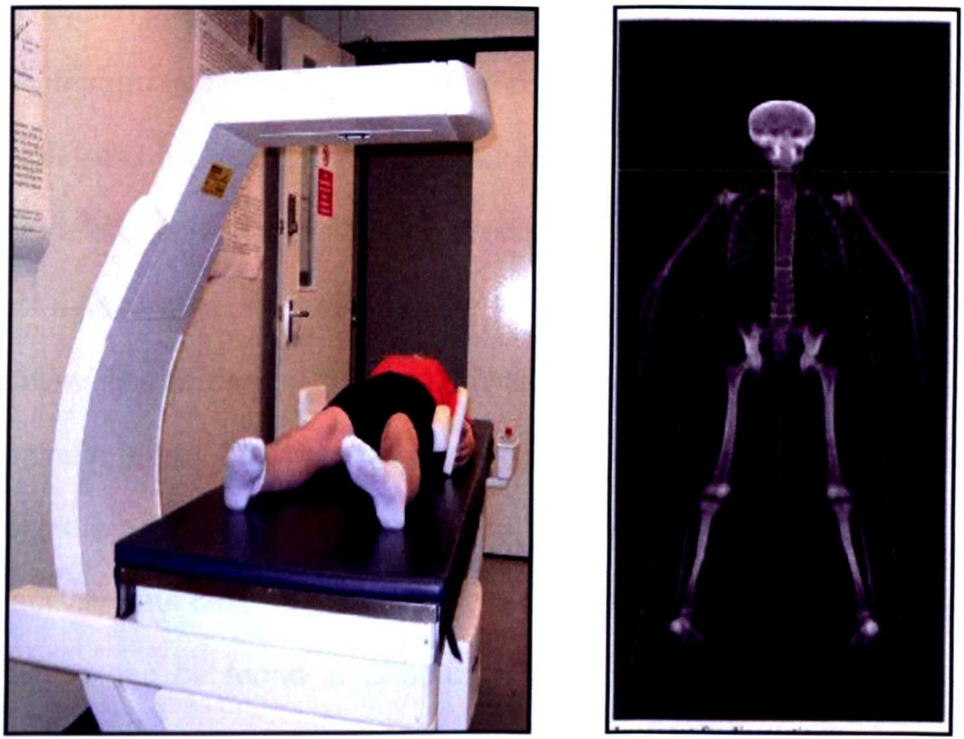

(a) (b)

Figure 3.2 Dual-energy X-ray absorptiometry whole body patient positioning (a) and scan image (b).

The DXA scanner was calibrated daily using the anthropomorphic spine provided by the manufacturer to assess accuracy of measurements. Graphs displaying calibration output for BMC, BMD and bone area at each of the assessment phases; February 2006 and June 2006 (Study 1), September/October 2006 (Study 2 and 3), June/July 2007 (Study 3) and October/November 2007 (Study 3) are attached displayed in Appendix A:2. The calibration for body composition variables was performed weekly using a step phantom supplied by manufacturers. The coefficient of variation (CV) for repeated measurements of variables at each time point is described in both studies (Chapter 4, 5 and 6).

3.1.4. Accelerometry: Habitual Physical activity

Habitual physical activity was measured using a uni-axial accelerometer; MTI Actigraph (MTI Health Services, Florida). The Actigraph (Fig. 3.3a) has been validated for use on children and was fitted on the right hip (Fig. 3.3b). All accelerometers were fitted on children in school. The accelerometer was set at 5-second epoch intervals. The total volume of physical activity including all intensities is termed the total physical activity and measured in counts per minute (cpm). Total physical activity was recorded as the average counts per minute over the period of recording (9hrs per day). The analysis of physical activity data differed between the study 1 and study 2 (&3), specific details of which can be found in Chapter 4, 5 and 6. Habitual physical activity was measured using a uni-axial accelerometer; MTI Actigraph (MTI Health Services, Florida).

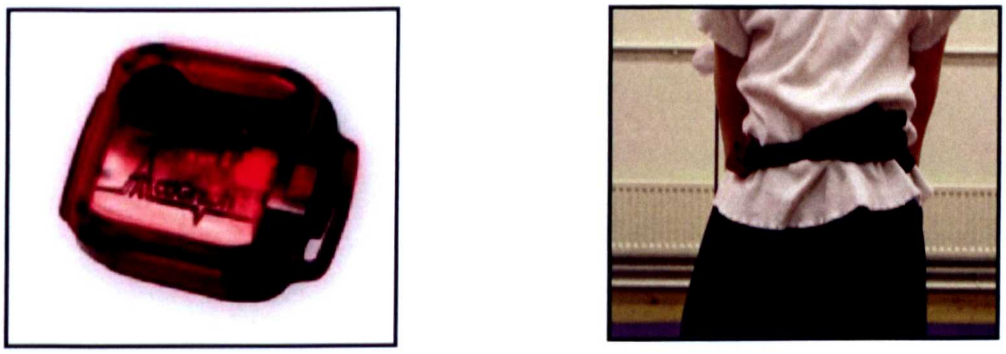


Figure 3.3 MTI uniaxial accelerometer (a.), positioning on left hip (b.)

Chapter
4

Study1: Exploratory Study

The effect of a 9-week physical activity programme on bone and body composition of children aged 10-11 years: The A-CLASS Project; An Exploratory Trial.

4.0 Study 1: Exploratory Study

The effect of a 9-week physical activity programme on bone and body composition of children aged 10-11 years: The A-CLASS Project; An Exploratory Trial.

This exploratory intervention study aimed to investigate the effect of a 9-week, structured high-impact after-school exercise programme and non-sedentary lifestyle intervention employed in the home environment on BMC, BMD and body composition in 10-11 year old children against age-matched controls. The purpose of this study was to test intervention approaches and effects in preparation for the longer 12-month intervention study.

The main outcomes of this study have been published in the International Journal of Sports Medicine. McWhannell, N., Henaghan J. L., Foweather, L., Doran, D. A., Batterham A. M., Reilly, T., Stratton G (2008). The Effect of a 9-Week Physical Activity Programme on Bone and Body Composition of Children Aged 10 - 11 Years: An Exploratory Trial *International Journal of Sports Medicine*. **29**, 941-947

4.1 Introduction

4.1.1 Bone, body composition and physical activity

Physical activity performed during childhood and adolescent years can promote optimal bone mineral accrual (Wang *et al.*, 2005; Janz *et al.*, 2006) and body composition [MacKelvie *et al.*, 2003; Abbott and Davies, 2004). It is believed that increased bone mineralisation from weight-bearing exercise before puberty is maintained into adulthood and may reduce the facture risk in later life (Bass *et al.*, 1998).

The volume of activity administered in interventions is a key variable to affecting bone measures significantly (Greene *et al.*, 2005) and has been considered to have a dose-dependent relationship with bone mineral density (BMD) (Scarpella *et al.*, 2003). High volumes of high impact loading activity are suggest to have an osteogenic benefit by reducing fracture risk (Bass et al., 1998) due to the osteogenic response caused by the biomechanical load on bone remodelling mechanisms (Wang *et al.*, 2005). Vigorous activity or intensity above 70% of maximal heart rate is also likely to have a favourable impact on body composition over time (Gutin and Owens, 1999; Gutin *et al.*, 2002). An inverse relationship between body fat and time spent in vigorous activity has been demonstrated (Denker *et al.*, 2006).

4.1.2 Previous Interventions

Numerous school-based exercise intervention studies in early pubertal children have shown positive effect of loading activity on bone mineral content and bone mineral density and little or no effect on body composition (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; McKay *et al.*, 2005). Such studies have used short-duration (10-12 minutes) high-intensity programmes of jumping over 7-8 months leading to significant increases of bone mineral content (BMC) and BMD in hip and lumbar spine regions of the body in pre-pubertal girls and boys. On the other hand in obese children, Barbeau *et al.* (1999) found significant increases in whole-body BMD, significantly reduced percent body fat, fat mass and increased fat free mass with a longer duration, multi-activity session over a shorter time period (4 months). Increasing duration or increasing frequency of short-duration regimens may contribute to greater benefits in bone and body composition. Positive changes in bone measures have been largely site-specific (MacKelvie et al., 2001; McKay et al., 2005) and inconsistent findings have been recorded in body composition outcomes (martinez Vizcaino et al., 2008, Gutin et al., 2002). The variability of volume and duration in such research makes it difficult to determine a minimum dose effect or to prescribe physical activity for bone mineral benefits.

Favourable body composition outcomes have also been acknowledged in interventions combining lifestyle education and exercise programmes (Gutin *et al.*, 2002; McMurray *et al.*, 2002). Significant decreases in percent body fat and visceral adiposity were found when lifestyle sessions were combined with physical training compared to lifestyle sessions alone (Gutin *et al.*, 2002). Without knowing the independent effect of physical training it is hard to ascertain the true combined effect. In a similar study on an adolescent population, McMurray *et al.* (2002) assessed education-only, exercise-only and education and exercise treatments combined. This short-term intervention (8-week) induced significant favourable changes in body fat, derived from two upper-body skin-fold sites.

This exploratory trial was designed within the spirit of the 'framework for development and evaluation of RCTs for complex interventions to improve health (Medical Research Council, 2000). We considered the inter-related theory and modelling phases of this framework together and, first, interrogated the literature to define the theoretical underpinning of the intervention and develop an understanding of its potential effects. Secondly, based on this evidence and our extensive practical experiences in health promotion projects within the education setting, we defined and standardised the intervention to maximise treatment fidelity. The trial was designed to be feasible and suitable for the school setting, offering minimal disruption in-school and practical timetabling for optimal parental support after-school.

4.1.3 Rationale

There is established research evidence suggesting bone mineral accrual and body composition can be positively influenced by physical training/exercise, but the extent to which exercise effects bone and body composition in a school exercise environment is unclear. There is also limited research to support the beneficial effect of interventions focusing on lifestyle approaches, particularly in bone-related research. The main aim of lifestyle interventions is to promote the sustainability of physical activity as part of free living through classroom-based education sessions rather than the more traditional direct contact with prescribed exercise programmes, with prescribed intensities and durations. A lifestyle programme that provides active prompts, motivational cues and suggestions or accessibility to local facilities alongside information on benefits of exercise, nutrition and health may bridge the void between the more traditional methods of physical activity promotion. A significant amount of resource has been given to schools to increase participation in physical activity, improve bone health and prevent obesity (PESSCL strategy, DFES, 2003). It is therefore important to find the most effective method of stimulating positive changes in bone mineral and body composition in children.

4.1.4 Aims

To provide important knowledge of practical and data collection processes through a feasibility study. The study aims to examine the extent to which structured physical activity (STEX) and lifestyle-based (PASS) physical activity affects bone health and body composition over a 9 week period in 10-11 year old children against age-matched controls (CONT).

4.2. Methods

4.2.1 Participants and settings

Eight primary schools in northwest England were invited to participate in the A-CLASS project based on school size (large), facilities (accessible space), current after-school club provision (limited) and socio-economic status (deprived). From the schools which noted an interest, three schools were randomly selected to participate. Each school was randomly assigned to one of three intervention groups, following a one-group-per-condition design (Murray *et al.*, 2004). It was decided not to randomise at the individual level within selected schools, as this approach may lead to contamination between intervention and control arms leading to an apparent dilution of intervention effects. Parents and children gave informed consent and assent respectively for participation in the study. Medical questionnaires were distributed to all children interested in the study. All children free from the presence of chronic disease, metabolic disorders, and prescribed medications including steroids inhaled by asthma sufferers were included in the study. Sixty-eight children met this criterion. Due to drop out and missing data, 36 healthy girls and 25 healthy boys aged 10-11 (11.0±0.3) years were retained for analysis (Consort statement Appendix C:2). Children attended university laboratories to undergo a series of physiological measures. All children were given information packs with detailed advice on physical activity and health.

4.2.2 Instruments and procedures

4.2.2i Anthropometry

Anthropometric measurements are described in detail in Chapter 3.

4.2.2ii Dual-energy X-ray Absorptiometry

In addition to the methods described in Chapter 3, the coefficient of variation (average from baseline and post measures) for the repeated measurements of total body BMD was 0.17%, for fat mass, 0.39% and for % body fat, 0.38%. Fat mass and lean mass were also indexed to control for differences in stature. Fat mass index (FMI) and lean mass index (LMI) were calculated by multiplying fat mass or lean mass by the square of stature (m^2).

4.2.2iii Assessment of Maturation

The participants completed a simple maturation picture questionnaire to self-assess and record their Tanner Stage (Tanner, 1978). This procedure was completed prior to body composition assessment. An example of the maturation questionnaire of boys and girls are attached (Appendix B:1).

4.2.3 Design and analysis

4.2.3i Intervention design

Physical activity interventions were conducted over 9 weeks during school summer term (April-July). A 9-week period was chosen to fit in with the school calendar and represented a minimum period for observing experimental effects.. These groups included a structured exercise intervention group (n=16), a lifestyle intervention (PASS) group (n=15) and a control group (n=30). In a one-group-per-condition design, the equivalence of groups at baseline is not secure. To address this threat to validity, the three schools selected were as similar as possible for the distribution of age, mass and socio-economic status.

The present design therefore constitutes a quasi-controlled non-randomised exploratory study, primarily to help establish a controlled intervention.

4.2.3ii Structured Exercise intervention (STEX)

Sixteen children (girls: n=13, boys: n=3) attended after-school A-CLASS club sessions of high-impact vigorous activity (duration 1 hour) twice weekly for a 9-week period during the school term. A trained multi-skills coach conducted the sessions, which included a combination of playground-style games and circuit training activities, the target was to maintain an average heart rate of above 75% heart rate reserve (~145 beats. min^{-1}) for the duration of the session. Three children were randomly selected to wear heart rate monitors (Polar Team System Interface) in the first, middle and last week of intervention period. In total 9 children (boys n=3, girls n=6) wore heart rate monitors over the intervention period, this was to confirm the vigorous nature of the sessions, analysed by Polar Precision Performance software (Polar Electro Oy, Kempele, Finland). A compliance of 75% attendance was required for subjects to be included in the study.

4.2.3.iii Physical Activity signposting scheme: (PASS)

The PASS intervention (Hepples and Stratton, 2007) is based on two theoretical behaviour change models: social cognitive theory (Bandura, 1986) and ecological theory (Sallis and Owen, 1999). Seven girls and 8 boys received weekly mail to their home in the style of a "mission" suggesting a task as a prompt to participate in physical activity during the week. This intervention aimed to encourage and incorporate physical activity (no specific intensity) into their lifestyle using an intervention mapping approach. The missions were based on a combination of both theories incorporating the benefits of physical activity including enhancement of confidence and skill, self-control, goal setting, active prompts and information on activity opportunities in different environmental contexts. Examples of missions include a pedometer challenge to increase steps per day, intelligent screen viewing to reduce time spent watching TV or playing on computer or console, family active challenge to encourage family participation in physical activity (all missions can be found in appendix B:3). Completed missions were returned to the university in a self-addressed stamped envelope. A compliance criterion of 75% attendance was required for children to be included in the study. In addition to the "missions", pedometers were given to the children as a promotional tool for the entirety of the project.

4.2.3.vi Control (CONT)

Sixteen girls and 14 boys in the control group received no form of intervention. They only received information on physical activity and health given in the information pack (British Heart Foundation, 2001) during baseline testing.

4.2.4 Statistical analysis

Statistical package SPSS (v12) was used to analyse data. Descriptive data comprised mean ± standard deviation (SD) of pre-intervention and post-intervention values unless stated otherwise. Analysis of covariance was conducted to compare the effectiveness of the 9-week physical activity intervention. The independent variable was the type of intervention group (STEX, PASS and CONT), with the dependent variable as the variable change score ('post' minus baseline). The baseline value for the variable was used as the covariate in this analysis, to control for any imbalances at baseline (Vickers and Altman, 2001) and additional covariates stature and body mass were included to adjust for differences in body size. Effects were evaluated for clinical significance (Batterham and Hopkins, 2006) by pre-specifying the minimum clinically importance difference (MCID). In the absence of a robust clinical anchor, the MCID is defined conventionally using a distribution-based method as a Cohen's *d* (standardised difference in the change scores between groups) of 0.2 between-subject standard deviations (Cohen, 1988). The SD of the pooled baseline scores was used for this purpose, as the post-test SD may be inflated by individual differences in responses to the intervention. The MCID was interpreted as 'benefit' or 'harm' according to the direction of the effect on the intervention for a given variable. The probability (percent chances) that the true population effect is beneficial (>MCID), trivial (within ± the MCID), or harmful (> MCID in the opposite direction) was calculated and interpreted according to the recommendations of Batterham and Hopkins (2006). Exploratory analyses through t-tests indicated no substantial gender difference in each group over the 9-week intervention; therefore, boys and girls were merged together in each group.

4.3 Results

4.3.1 Descriptive Characteristics

Full data sets were gathered from 61 out of the original 68 participants (Girls n=36, Boys n=25). Six children from the control group and one from the PASS intervention were lost to follow-up, due to pupils moving schools and compliance. All of the children included in the intervention groups achieved 75%

attendance to STEX or 75% compliance to PASS. Mean heart rate for the 60-min session was 155±7 beats.min^{-1}.. Descriptive data, characterised by intervention group are shown in Table 4.1.

Table 4.1. Baseline (pre) and post-intervention values for descriptive variables of control, lifestyle PASS and structured exercise group.

		Control	±	SD	Lifestyle PASS	±	SD	Structured Exercise	±	SD
N		30			15			16		
Age (yrs)	**PRE**	11.01	±	0.30	11.03	±	0.29	11.07	±	0.29
	POST	11.24	±	0.31	11.23	±	0.41	11.32	±	0.31
	Δ	0.2	±	0.3	0.2	±	0.3	0.2	±	0.3
Mass (kg)	**PRE**	40.7	±	7.9	40.6	±	8.9	41.4	±	10.7
	POST	44.8	±	9.4	42.4	±	9.6	42.9	±	11.1
	Δ	4.1	±	7.4	1.7	±	8.4	1.5	±	10.6
Stature (m)	**PRE**	1.48	±	0.09	1.44	±	0.07	1.48	±	0.07
	POST	1.49	±	0.09	1.46	±	0.07	1.50	±	0.07
	Δ	0.01	±	0.09	0.02	±	0.07	0.02	±	0.07
BMI (kg.m^{-2})	**PRE**	19.8	±	3.1	19.3	±	3.0	18.7	±	3.3
	POST	19.9	±	3.1	19.7	±	3.3	18.8	±	3.3
	Δ	0.1	±	0.5	0.4	±	0.5	0.1	±	0.3
Waist circ. (cm)	**PRE**	69.7	±	9.6	68.0	±	10.1	65.6	±	10.9
	POST	70.9	±	10.7	68.5	±	9.5	64.9	±	10.9
	Δ	1.2	±	4.7	0.5	±	2.7	-0.7	±	-2.7
Tanner Stage (1/2/3/4/5)	**PRE**	4/15/7/2/0			5/4/5/0/0			2/7/6/0/0		
	POST	1/13/13/3/0			2/4/8/0/0			1/3/11/0/0		
	Δ	-3/-2/6/1/0			-3/0/3/0/0			-1/-4/5/0/0		
Ethnicity (White/Black/Asian)		27/1/2			14/1/0			16/0/0		

Mean baseline and post intervention values ± SD and change (Δ) are listed for each group. Self-evaluated Tanner stage for girls (breast) and pubic hair (boys) development.

Baseline results showed no significant differences between groups at baseline for any descriptive, bone or body composition variables. Post-intervention, body mass increased in all groups, with the least increase displayed by the STEX group; BMI increased by 0.1 unit in both STEX and CONT group, whereas the lifestyle PASS group, demonstrated the greater increase in BMI (0.4) over the 9-week period (Table 4.1)

4.3.2 Bone Results

Raw change scores from baseline to 9 weeks for each of the intervention groups are shown in Table 4.2. The ANCOVA adjusted change scores revealed that compared to the control group, the STEX group attained a mean increase in BMC$_{TB}$ of 63.3g (95% CI for the difference in change between groups: 10.8 to 115.8, *P*=0.019). The probability (percent chances) that the true population effect is clinically beneficial/trivial/harmful is 78/22/0. We observed an increase of 0.011 g.cm^{-2} (95% CI: 0.002 to 0.021) for BMD$_{TB}$ (*P*=0.018). The percent chances of population clinical benefit/trivial effect/harmful effect was 37/63/0. Subjects in the STEX group increased their total body BMC and BMD by 12.3% and 2.7% from baseline respectively. Mean increases demonstrated from the PASS group compared with control group were not significant (P>0.05) or clinically relevant. The mean changes observed by the STEX group alone satisfied the criteria for the smallest clinically worthwhile effect (benefit) for BMC$_{TB}$ (Figure 1), $_{FN,}$ and BMD$_{TB\ FN,\ LS}$. The mean difference in the change scores between the STEX and the control group also met this criterion for BMC$_{TB}$, indicating that the STEX intervention had a clinically relevant effect on bone mineral content compared to control. No significant change was recorded within the STEX group for BMC$_{FN}$, BMD$_{FN}$, (*P*=0.11; *P*=0.81) or BMC$_{LS}$ and BMD$_{LS}$; *P*=0.78; *P*=0.47). Nor were there any significant changes recorded by PASS group for BMC$_{FN}$, BMD$_{FN}$ (*P*=0.15; *P*=0.51) or BMC$_{LS}$ and BMD$_{LS}$ *P*=0.26; *P*=0.42) compared to control group. The PASS group did satisfy criteria for smallest clinically worthwhile effect (benefit) for BMC$_{TB}$ (Figure 4.1) and BMD$_{TB.}$

Table 4.2. Baseline (PRE), post-intervention (POST) and change (Δ) values from each outcome variable for CONT, PASS and STEX group

		CONT (n=30)	± SD	PASS (n=15)	± SD	STEX (n=16)	± SD	
$\mathrm{BMD_{TB}}$ (g.cm^{-2})	PRE	0.850	± 0.06	0.865	± 0.07	0.848	± 0.04	
	POST	0.860	± 0.06	0.878	± 0.07	0.871	± 0.05	
	Δ	0.011	± 0.01	0.013	± 0.01	0.023	± 0.01	*
$\mathrm{BMC_{TB}}$ (g)	PRE	1262.70	± 230.65	1251.85	± 223.05	1223.06	± 171.22	
	POST	1345.33	± 228.96	1309.09	± 230.73	1373.98	± 179.14	
	Δ	89.71	± 99.03	57.24	± 30.51	150.92	± 88.51	*
$\mathrm{BMD_{FN}}$ (g.cm^{-2})	PRE	0.778	± 0.09	0.778	± 0.07	0.755	0.07	
	POST	0.791	± 0.09	0.795	± 0.07	0.772	± 0.07	
	Δ	0.010	± 0.04	0.010	± 0.02	0.010	± 0.01	
$\mathrm{BMC_{FN}}$ (g)	PRE	22.24	± 4.48	20.37	± 4.24	20.67	± 4.24	
	POST	22.09	± 4.18	20.94	± 4.18	21.86	± 4.28	
	Δ	-0.26	± 2.67	0.57	± 0.96	1.19	± 1.12	
$\mathrm{BMD_{LS}}$ (g. cm^{-2})	PRE	0.634	± 0.07	0.657	± 0.10	0.654	± 0.07	
	POST	0.655	± 0.08	0.666	± 0.10	0.676	± 0.08	
	Δ	0.017	± 0.02	0.009	± 0.02	0.022	± 0.01	
$\mathrm{BMC_{LS}}$ (g)	PRE	29.41	± 6.47	30.19	± 6.79	29.67	± 6.19	
	POST	30.63	± 6.86	30.12	± 6.30	30.84	± 7.25	
	Δ	0.92	± 1.70	-0.06	± 1.98	1.16	± 1.97	
FMI (g.m^{-2})	PRE	5489.77	± 2300	5032.88	± 1930	5137.29	± 2348	
	POST	5773.37	± 2318	5404.38	± 2060	5295.08	± 2481	
	Δ	283.60	± 423	371.50	± 405	157.79	± 229	
LMI (g.m^{-2})	PRE	13855.2	± 2300	13932.7	± 1463	13206.7	± 1229	
	POST	14253.1	± 1239	14391.6	± 1604	13757.1	± 1179	
	Δ	397.89	± 403	458.89	± 371	550.37	± 368	
Body Fat (%)	PRE	26.65	± 7.4	25.06	± 5.8	26.24	± 7.3	
	POST	27.11	± 7.1	25.75	± 5.9	25.96	± 7.6	
	Δ	0.46	± 1.6	0.69	± 1.5	-0.27	± -1.0	
Trunk Fat (%)	PRE	21.47	± 8.3	19.35	± 6.9	20.41	± 7.7	
	POST	22.44	± 8.2	20.65	± 7.2	20.56	± 8.2	
	Δ	0.970	± 2.1	1.3000	± 2.0	0.1500	± 1.5	

* Change (Δ) is significantly greater than the change observed by the control group ($P<0.05$)

4.3.3 Body Composition Results

Fat mass and lean mass was indexed (fat or lean mass x stature^2). The increase of mean fat mass index (FMI) was not significant in STEX (2.9%; P=0.31) or PASS intervention (6.3%; P=0.42) compared to those in CONT group (4.9%). No observed increases in FMI satisfied the MCID criterion for harm. Lean mass index (LMI) change increased in all groups over the 9-week intervention period, though not significant compared to changes demonstrated by CONT. Lean mass index increased by 4.2% in STEX group (P=0.29); PASS, 3.1% (P=0.60), with CONT increasing LMI by 2.8%. All groups exceeded the

MCID change score of 279 g.m^{-2}. Compared to the control group, no significant FMI or LMI changes were observed by either intervention group despite a reduction of 1.1% in percent body fat by STEX group (*P*=0.09), percent body fat increased by 1.7% and 2.6% in PASS and CONT groups, respectively (*P*>0.05). Neither intervention satisfied the MCID criterion for benefit.

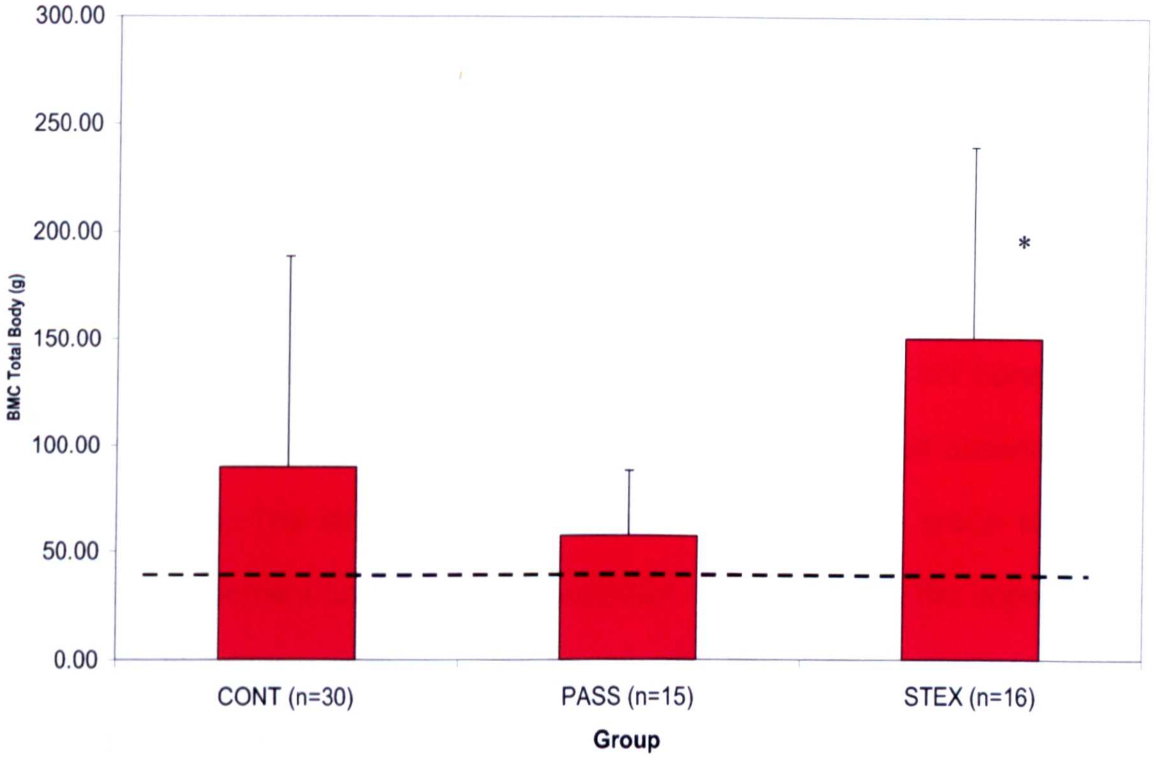


Figure 4.1. Change in total body bone mineral content (g) over 9-weeks for each intervention group; CONT, PASS and STEX. .

Total body BMC increased significantly in the STEX group compared to CONT group over 9-week intervention.

* Change is significantly greater than change in control group (*P*<0.05), analysis of covariance.

- - - MCID marker for benefit to health (Change of 42.8g)

4.4 Discussion

In this 9-week high-impact physical activity intervention, significant and clinically important bone mineral accrual was attained through STEX activity performed for 60 min twice per week. Accelerated bone mineral increases and small but favourable changes in body composition were observed after the structured exercise intervention compared to the age-matched controls. The calculated probability that the observed effect for total body BMC is clinically beneficial of 0.78, suggests that the intervention is *likely to be* clinically relevant (Batterham and Hopkins, 2007). For total body BMD the picture was less clear, with a probability of clinical benefit of 0.37 (*possibly* beneficial). Clearly, a larger definitive trial is required to define these potential benefits. For both BMC and BMD, however, the percent chance of harm (defined as a change greater than the MCID but in the opposite direction) was zero.

4.4.1 Intervention effect: Bone

The positive effect of the structured exercise intervention on bone mineral content amounted to a 68% greater change in BMC than that observed in the control group. The structured exercise group was the only group to show a reduction in percent body fat. Taken together, results support the importance of vigorous high-impact activity. The volume (60-minutes twice weekly) may also be influential when implementing realistic exercise programmes to enhance bone mineral accrual, with significant effects realised over a relatively short period of 9 weeks. The lifestyle PASS group only displayed accelerated changes (over and above the changes observed by control group) in BMD_{TB} and LMI measures. A positive change recorded by the PASS group in BMD but not BMC may in part be explained by growth in body stature; BMD is calculated from BMC and bone area (BMC x BA) and bone area increases with stature. A greater change in stature was observed by the lifestyle PASS group (0.2 cm) compared to the control group (0.1), which in turn would display a greater BMD score in lifestyle PASS than in the control group.

The magnitude of change in BMC_{TB} achieved by the structured exercise group in this study (150 g) is greater (60 g) than the change observed by Barbeau *et al.* (1999) of 90 g using a 40-minute high-intensity training performed on an average 4 times weekly for 4 months with obese children of a similar age. This study evaluated 61 children within a small age range of 10-11 year old children, whereas Barbeau *et al.* (1999) assessed 71 children within a greater age range of 7-11 year olds. The narrow age range in the present study may account for the greater change observed due to the effect of maturation (early pubertal) on bone associated with children of such age (Bass *et al.*, 1998); Is likely that on average more children in the 10-11 year age range will experience some maturational changes compared to children in a 7-11 year group because of the larger age range.

Changes in total body BMC and BMD reported in this study are also consistent with jump-based research in girls (10 min jump-circuit x 3 per week) of similar maturity carried out over a longer period of 7 months by MacKelvie *et al.* (2001) despite no significant changes reported. Few previous studies have yielded evidence of increases in total body BMC or BMD; most reported site-specific increases in hip and spine regions (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; McKay *et al.*, 2005). The dynamic nature of the physical activity in the STEX programme may have accounted for the significant total body accrual of bone rather than that of key weight-bearing regions. Whilst the games and activities performed in the sessions were impacting in nature, they did not replicate intense loading activities performed in previous studies (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; McKay *et al.*, 2005). This may have promoted acute mineralisation throughout the skeleton, theorised by Zhang *et al.*, (2006), rather than localised mineralisation in the femoral and lumbar regions, which are known to respond fastest to changes in mechanical load due to the high proportion of trabecular bone (Heinonen *et al.*, 2000; Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001, 2003). Therefore, the significant increases in this study may have been evident only when the total changes are aggregated rather than expressed in separated anatomical regions. Non-site specific bone adaptation has been acknowledged in literature (Zhang *et al.*, 2006) but there is little supporting research to confirm this theory. Previous intervention studies (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; McKay *et al.*, 2005) reporting significant increases in bone mineralisation have exceeded 7 months thus the length of the intervention duration may have also been a limiting factor for bone remodelling in regional bone mineral accrual.

Had habitual physical activity been measured over the intervention period, the assessment of total physical activity (Intervention activity + habitual activity) would have allowed a stronger insight into observed changes in bone mineral accrual and may have harboured a robust association between games-like activities (within STEX), children's free-play activity (habitual activity) and bone health. The intensity of habitual physical activity is a key factor, there is a common consensus that vigorous physical activity is likely to be more osteogenic than light physical activity, although discrepancies in the literature provide weak evidence for this (Hasselstrom *et al*, 2007., Ginty *et al.*, 2005).

Never-the-less, the monitoring of habitual activity in addition to intervention activity is essential and combined with objective and accurate measures will provide stronger research evidence.

4.4.2 Intervention effect: Body Composition

Changes in fat mass, lean mass and percent body fat in this study followed a similar trend to those reported by Gutin *et al.* (1999) with obese children, although Gutin *et al* (1999) reported a significant reduction in percent body fat. Despite the populations being slightly different (The average BMI of children in the current study was classified as overweight (BMI = 19.75; Chinn and Rona, 2004), it is likely that the length and or volume of training in the intervention may have been a contributory factor. Gutin *et al.* (1999) delivered a 4 month multi-activity training programme of 4 x 40 min per week, compared to 9 week, 2 x 1 hr per week in the present study. Significant decreases in percent body fat were also evident when Gutin *et al.* (2002) combined lifestyle and structured exercise in a later study, but did not measure their separate effects making it difficult to ascertain if individually, the exercise programme was an effective stimulus. Despite non-significant changes in body composition in this current study, the STEX and PASS intervention data illustrate positive changes regarding smallest clinically worthwhile effect in fat-free lean mass and fat mass but not for percent body fat despite the reduction of percent body fat found in the STEX group performing structured exercise. However, reduction of percent body fat found in the STEX group is noteworthy, particularly as the CONT and PASS groups, and the population as a whole are accumulating body fat. The STEX intervention may be beneficial at reducing or minimising fat accumulation which is of health benefit.

4.4.4 Limitations

The sex imbalance present in the STEX group may have contributed to magnitude of BMC_{TB} change observed when compared to the more homogenous PASS and CONT groups. Bone can become more sensitive to external mechanical stimuli during maturation, particularly in females due to the increase in oestrogen production (Barbeau *et al.*, 1999; Heinonen *et al.*, 2000). Most girls in each group self-reported Tanner Stage 2-3, therefore given the sample size differences and sex imbalance, such hormone mechanisms may have contributed to the change observed by the STEX group. However, any confounding results due to sex imbalance is likely to be small as there was no significant Tanner stage difference between groups.

The method of delivery of the intervention programmes may have contributed to the differential results. The STEX intervention followed a more didactic approach where children attended after-school sessions of organised game activities and were encouraged and motivated to work at a high intensity. The PASS intervention drew on behaviour change models prompting children with ideas, suggestions and tasks to participate in physical activity within their daily routine and allowing the children to take more responsibility for their activity. This approach holds more ecological validity and if adhered to should provide a higher probability of sustained physical activity after the intervention has finished. On the other hand a more structured and directed approach toward physical activity programming according to the main outcome of this study is more advantageous.

As three schools were randomly assigned to one of three conditions, it is acknowledged that it is therefore not possible to account properly for the design effect of the clustering by school, as there is one school in each cluster. Hence the cluster component of variance was ignored and data analysis was conducted at the level of the individual. This resulted in the precision of the estimate of the mean intervention effect being somewhat overestimated (narrower confidence limits).

4.4.5 Future work

This feasibility study provides useful information for a larger definitive trial. For example, with respect to sample size planning, the observed reliability of one of the main outcome measures (total body bone mineral content) was r=0.91 (95% CI, 0.86 to 0.94; correlation between pre-test and post-test scores). With 2 P=0.05, 90% power to detect an MCID of 0.2 between-subject standard deviations, and the lower limit of the confidence interval of the reliability (to provide a more conservative estimate), the ANCOVA estimation method (Frison and Pocock, 1992) produces a required sample size of 136 children in each group. The appropriate allowance for attrition may be estimated from the drop-out recorded in this exploratory trial. The attrition recorded was circa 10% (7/68; 95% CI, 3% to 18%). Taking the upper limit (18%) as a conservative estimate, the sample size is inflated to 166 in each group (136/0.82).

The current findings justify a larger longitudinal study to replicate the findings on bone measures and explore maturational effects. The use of the maturity offset calculation (Mirwald *et al.*, 2002) could be used to provide a more sensitive measure of maturational status than Tanner stage assessment. The limitations of the self-report method are acknowledged, as the stages were not confirmed by a health-care professional in this study. Further recommendations for future study may include dietary intake and physical activity monitoring to establish influences of lifestyle and habitual activity.

4.5 Conclusions

The present results showed that structured exercise sessions conducted after school that focused on high-impact activity had a significant clinically beneficial effect on whole-body bone mineral accrual and indicate encouraging changes in body composition over and above any positive changes observed from the lifestyle (PASS) intervention and control groups. Present findings support the need for the promotion of high-impact exercise for growing children and suggest the best method of implementation is through a realistic and feasible structured school-based programme.

These exploratory findings provided a sound rationale for implementing a year longer (12 month) intervention study. The trial showed the STEX and PASS intervention programmes to be feasible in primary school children. The volume of intervention sessions was supported by the school. Although the study design was feasible, we aim to improve it by introducing assessment of physical activity. The PASS missions were also supported by school but we feel that better compliance would be evident though weekly contact with a PASS coach to help keep participants motivated. Given the success of the STEX activity, we would like to introduce another structured activity treatment; fundamental movement skill based activities. Therefore the longer study will aim to assess the differential effect of 3 different year long physical activity interventions on the bone mineral accrual body composition of 9-10 years old children.. In order to track participants over 12 months, we would have to start the intervention at the start of primary year 5 to complete at the start of year 6, therefore the age group was changed from 10-11 year olds to 9-10 year olds. In order to keep participants motivated over 12 months we would introduce a reward scheme to reward participants for complience throughout the intervention.

The following studies report the relationships between bone mineral, body composition and physical activity in a small correlation study (study 2) and the findings from a 12 month intervention (study 3): A-CLASS intervention project.

Chapter

5

Study 2: Small scale correlational study

Physical activity and the Relationships with bone mineral status, body composition and physical activity in 9-10 year old children.

The A-CLASS Project

Chapter 5: Study 2; Small scale correlational study

5.1 Introduction

Prior to assessing the effect of intervention programmes on health measures such as bone mineral accrual, body fatness and habitual physical activity it is important to explore the relationships between such health measures.

Findings from a representative sample of children in Liverpool, estimate that one third of children are overweight or obese in the UK (Stratton *et al*, 2007). Whist the prevalence of obesity in children has increased, the reported time spent in physical activity in children have fallen (Stratton *et al.*, 2007). Previously it has been estimated that approximately two-thirds of overweight children show evidence of cardiovascular risk factors (Gutin *et al.*, 1994., Deitz, 2004., Rizzo *et al.*, 2007), which are linked to body fatness and also to physical activity (Andersen *et al.*, 2006). It is believed that regular physical activity may reduce susceptibility to early onset of chronic disease such as obesity-related diseases in adulthood (Lui-Ambrose *et al.*, 2001, Abbott and Davies., 2002., Andersen *et al.*, 2006).

Some sources report that children, particularly girls are not achieving the current recommended guideline for physical activity (Sproston , 2003., Riddoch *et al.*, 2007), while others confirm that 60 min per day guideline is being met by children (HSE, 2003). Riddoch *et al.* (2008) also found that, not only are a large proportion of children not meeting guidelines, the activity performed does not satisfy a level (intensity and duration) that would promote cardio-respiratory fitness. Either way, risk factors such as increased body fat and low cardio-respiratory fitness are still apparent in children. If children are meeting current activity guidelines, it could be suggested that 60min of moderate activity is inadequate to protect again risk factors, or that the intensity of activity is inadequate to promote health benefit. It could also be suggested that food consumption rather than inactivity may be the key precursor of risk factor development.

Findings from the European Youth Heart Study (Andersen *et al*, 2006) suggest that physical activity guidelines for children need to be increased to 90 min per day for 15 year olds and 116 minutes for 9 year olds of moderate to vigorous activity to prevent the development of insulin resistance. Andersen *et al* (2006) found a graded negative association between PA and risk factor clustering. The study also found that children who engaged in >40 min of vigorous physical activity each day had significantly lower body fat than those participating in 10-18 minutes each day (Ruiz *et al*, 2006).

Abbot and Davies (2004) found that children who spent more than 125 minutes in vigorous intensity activity and more than 15 min in very vigorous activity per day had significantly lower percent body fat, than children who spent less than 125 minutes and 15 minutes in vigorous and very vigorous activity per day. Physical activity (duration and intensity) is also a key factor in bone health development. Active children have been found to possess greater bone mineral density than inactive children (Scarpella *et al.*, 2003; Janz *et al.*, 2004). Sport-specific bone research with gymnasts (Scarpella *et* *al.*, 2003.; Ward *et al.*, 2005), game players (Vicente- Rodriguez *et al.*, 2004) and athletes (Greene *et al.*, 2005) has suggested a dose-dependant relationship between time spent in physical activity and bone mineral density (Scarpella *et al.*, 2003., Vicente- Rodriguez *et al.*, 2004. Intervention programmes prescribing high levels of physical activity/exercise support this association (MacKelvie *et al.*, 2003; Fuch *et al.*, 2001; Linden *et al.*, 2006). The relationship between physical activity and peak bone mineral accrual was studied during growth over a 6-year longitudinal study (Bailey *et al.*, 1999). The study indicated that peak bone mineral accrual could be maximised by high levels of activity during childhood.

It has also suggested that active children are able to accrue between 10-40% increases in bone mass in the 2 years surrounding this period of peak bone velocity than other less active peers (Bailey *et al.*, 1999).. Conversely, low levels of physical activity in childhood may lead to low peak bone mass and low BMD which are likely to increase susceptibility to fracture in later adulthood.

5.1.1 Aims

The purpose of this correlational study was to assess gross correlations bone mineral status, body composition and physical activity, in particular, the volume and intensity of activity to examine the dose-response relationships. This is the only study to the authors' knowledge where body composition, bone health and habitual physical activity are measured objectively in a cohort of pre-pubertal English children.

5.2 Method

5.2.1 Subjects and settings

One hundred and fifty-two children participated in the study. The children came from 8 randomly selected primary schools within a Metropolitan Borough from North West England. Ethical permission was obtained from the institution's Research Ethics Committee. Parents and children gave informed consent and assent respectively for participation in the study. Medical questionnaires were distributed to all children interested in the study. All children free from the presence of chronic disease, metabolic disorders, and prescribed medications including steroids inhaled by asthma sufferers were included in the study.

5.2.2 Instruments and procedures

In addition to the anthropometric measures, bone mineral, body composition, and physical activity assessment described in detail in Chapter 3, the following were included in the methodology of this study.

5.2.2.i Skin-fold assessment

Multiple skin-fold measures were taken to account for morphological and fat distribution in addition to DXA data. Skin thickness was measured by a researcher trained to standards of the International Society for the Advancement of Kinanthropometry (ISAK). Subcutaneous fat was measured in various regions on the body using Harpenden skin-fold callipers (Harpenden, UK). An 8-site skin-fold procedure was used, the sites included; Triceps, subscapular, biceps, iliac crest, supraspinale, abdomen, front thigh and medial calf. Girth measurements were also taken using a tape measure (Lufkin W606PM, Cooper Tools Inc. UK) including waist circumference (natural waist), Gluteal circumference (providing waist-to-hip ratio), arm girth relaxed, arm girth flexed and tensed, and calf girth. Bone breadths were also measured using a small sliding calliper (Rosscraft Inc.) on the biepicondyles of the humerus and femur. All skin-fold and girth measurements were taken at least two times and repeated if measurement error was >5% for skinfolds, >1% for girths and >1% for bone breadths between first and second measurement. All measurements were taken according to the procedures outlined by ISAK (Marfell-Jones, 2006) and were recorded in an Excel spreadsheet proforma (Appendix C:1). The sum of 4, 7 and 8 skin-folds was recorded to assess participants' body fat and to explore relationships between skin-fold assessment and DXA assessment and other variables.

The sums were calculated as:

∑4= triceps, subscapular, supraspinale, medical calf

∑7= triceps, subscapular, biceps, supraspinale, abdomen, front thigh and medial calf

∑8= triceps, subscapular, biceps, iliac crest, supraspinale, abdomen, front thigh and medial calf

5.2.2.ii Physical activity inclusion and assessment criteria

Complete data from at least 3 weekdays was required to be included in analysis. The total volume of physical activity including all intensities is termed as total physical activity and measured in counts per minute (cpm). Total physical activity was recorded as the average counts per minute over the period of recording (9 hours per day). In terms of time spent in physical activity, individual calibration was acquired from accelerometer data recorded from treadmill walking and running obtained from the $\dot{V}O_{2Peak}$ assessment (not reported). Using activity counts, percent of $\dot{V}O_{2Peak}$ and treadmill speeds we were able to quantify intensity of activity to equivalent speeds of locomotion. The average total time-spent in physical activity of intensity equivalent to 4km/h or greater per day was recorded.

5.2.2.iii. Assessment of Maturation

Maturation was estimated using maturity prediction calculation (Mirwald *et al* 2002). Sitting height, mass, stature and age are used in a maturity offset calculation to estimate the number of years from peak height velocity (period of maximum growth).

Mirwald et al (2002) Predicting PHV Equation:

$$\textbf{Maturity Offset} = -9.236 + [0.0002708 * (\text{leg length} * \text{sitting height})] + [-0.001663 * (\text{age} * \text{Leg length})] + [0.007216 * (\text{age} * \text{sitting height})] + [0.02292 * (\text{mass/stature})]$$

This calculation gives a valuable insight into biological age which is fundamental to intervention research where children may be maturing at different rates. The measurement of maturity offset allows researchers to correct for individual variability of somatic and biological growth. The effect maturation has on bone mineral accrual and body composition has been previously discussed.

5.2.2.vi Measurement error DXA

Bone mineral content (g) and density ($g.cm^{-2}$) along with fat mass (FM), lean mass (LM) and relative fat mass (%) were determined by means of dual-energy x-ray absorptiometry (DXA: Hologic QDR series Discovery A Fan-beam, Bedford, Massachusetts). The coefficient of variation (CV) for repeated measurements of bone mineral and body composition by DXA analysis were BMC_{TB}, 0.24%, BMD_{TB}, 0.21%, BMC_{FN}, 1.86%, BMD_{FN}, 0.56% , BMC_{LS}, 0.64% BMD_{LS}, 0.40%, FM, 0.32%, %BF, 0.36%.

5.2.3 Design and analysis

Children were recruited to participate in a longitudinal research study; the A-CLASS Project. This small scale correlational study assesses gross correlations using the descriptive baseline data from this cohort.

5.2.3.i Data Collection

Laboratory data was collected when children visited the Research Institute laboratories at Liverpool John Moores University. All children were given information packs with detailed advice on physical activity and health, any further explanation was given verbally. Physical activity data were obtained from visiting children in school to distribute and collect activity monitors. Physical activity monitors were given to children on one day and collected from them 7 days later. The accelerometers were then downloaded and data was assessed using MAHUFFE software.

5.2.3.ii Statistical Analysis

Statistical analyses were performed using SPSS v.14 (SPSS Inc., Chicago, USA). The significance level of 0.05 was used throughout the analyses. Mean (M) and standard deviation (SD) of variables were recorded for the complete sample and by sex. The following statistical procedure was carried out:

1.. Partial correlation (r=correlation coefficient) analysis was performed to investigate relationships between bone mineral and body composition variables and physical activity, with maturity offset as the controlling variable. Although no significant maturational difference was found; when maturity status was introduced into the model as a covariate significant relationships were strengthened.

2. Regression analysis was performed to find the best predictor of BMC and D, using LM, FM, Mass, and Maturity offset as predictor variables.

3. Total time spent in physical activity was analysed further comparing relationship with variables for time thresholds of physical activity; with less than 60 minutes, 60-90 minutes and over 90 minutes of time spent in physical activity, and at differing intensities.

4. Skin-fold data, BMI and anthropometric measures of adiposity were correlated (partial correlation)with total fat mass (g), percent trunk and total fat body derived from DXA to explore the best field-based methods to assess adiposity risk in the absence of DXA.

5.3 Results

5.3.1 Descriptive characteristics

Out of the original 152 children who were selected for inclusion in this study, complete anthropometric data were obtained on 149 children, successful PA data was achieved by 144 children, complete DXA assessment was attained by 134 children (consort statement: Appendix C:2). Mean (M) and standard deviation (SD) values for descriptive variables by sex are presented in Table 5.1. Ethnicity distribution was similar within gender groups.

Table 5.1. Descriptive anthropometric characteristics and skin-fold thickness values for the sum (∑) of 4, 7 and 8 measuring sites.

	All		Girls		Boys		
Variable	**n=149**		**n=89**		**n=60**		***P***
	M	**SD**	**M**	**SD**	**M**	**SD**	
Age (years)	9.70	0.38	9.68	0.36	9.72	0.42	
Mass (kg)	36.7	8.36	36.5	8.10	36.9	8.79	
Stature (m)	1.39	0.06	1.38	0.06	1.39	0.07	
Sitting Stature (cm)	72.96	3.40	72.61	3.31	73.47	3.48	
BMI (kg/m2)	18.93	3.15	18.95	3.05	18.89	3.31	
BMI group (nonOW/OW/OB)	78/53/18	-	51/31/7	-	27/22/11	-	
Waist Circ. (cm)	62.89	7.37	62.22	6.92	63.87	7.94	
Waist:Hip ratio	0.83	0.04	0.82	0.04	0.85	0.04	*
Maturity Offset (years to PHV)	-3.29	0.45	-3.32	0.44	-3.23	0.48	
SF sum4	56.07	23.04	59.01	21.96	51.75	24.09	
SF sum7	108.57	42.93	113.60	40.37	101.19	45.78	
SF sum8	125.62	50.26	130.75	45.66	118.09	55.87	

* sex difference *P*<0.001
nonOW = non overweight, OW = overweight, OB = Obese (Chinn & Rona, 2004)

Between-sex differences in descriptive variables were not substantial (other than waist-to-hip ratio; P>0.001) although there was a trend for greater body size (mass, stature and waist circumference) in the boys, where as girls had greater skin-fold and BMI values. From this point the groups were pooled and analysed as one sample.

Skin-fold assessed body composition data was obtained from 148 children at baseline. Table 5.1 displays mean (M) and standard deviation (SD) values for the sum of 4, 7 and 8 anthropometric skin-fold measures. Mean and standard deviation values for each individual site can be found in Appendix C:3).

5.3.2 Body composition and bone mineral content/density

One hundred and forty-six data sets for total body bone mineral and composition were obtained (n=146; girls n=89, boys n=57). Lumbar spine (n=146) and femoral neck (n=437; girls n=88, boys n=55) bone scans were also completed. The mean (M) and standard deviation (SD) values of bone mineral and body composition data by sex are reported in Table 5.2.

Table 5.2. Body composition values from total body DXA scan and bone mineral content (BMC) and bone mineral density (BMD) for the total body (TB), femoral neck (FN) and lumbar spine (LS).

Body composition and bone	All		Girls		Boys		
	n=146		n=89		n=57		*P*
	M	SD	M	SD	M	SD	
Fat mass (kg)	10.6	4.79	11.2	4.55	9.83	5.08	
Total Arm Fat mass (kg)	1.50	0.63	1.50	0.60	1.29	0.68	
Total Leg fat mass (kg)	4.63	2.00	4.87	1.87	4.25	2.10	
Trunk fat mass (kg)	3.81	2.27	4.03	2.18	3.47	2.40	
Total Body Fat (%)	27.6	6.55	29.3	5.69	24.9	6.92	**
Percent Trunk Fat (%)	22.3	7.37	24.0	6.76	19.5	7.49	**
Lean mass (kg)	25.4	4.33	24.7	4.10	26.5	4.49	*
Total Arm lean mass (kg)	2.28	0.43	2.17	0.40	2.45	0.41	**
Total Leg lean mass (kg)	8.42	1.63	8.24	1.59	8.70	1.67	
BMC_{TB} (g)	1096.9	130.7	1071.6	125.1	1136.4	130.6	*
BMD_{TB} (g.m-2)	0.82	0.05	0.81	0.05	0.84	0.05	**
BMC_{FN} (g)	17.06	3.06	16.66	2.87	17.70	3.27	*
BMD_{FN} (g.m-2)	0.73	0.07	0.71	0.06	0.76	0.06	**
BMC_{LS} (g)	24.27	4.12	23.91	4.42	24.82	3.56	*
BMD_{LS} (g.m-2)	0.61	0.07	0.62	0.08	0.61	0.05	

* Sex differences P<0.05, ** sex differences P<0.001

5.3.4 Physical activity

Physical activity data (M and SD) from 144 children (girls n=85, boys n=59) is described in Table 5.3. The criterion for inclusion in analysis was 3-days wear time; of at least 9 hours per day. Total physical activity (PA_{Total}) is any physical activity above 100 cnts.min^{-1}, time spent in activity equivalent to and above 4 km/h (PA_4) and 8 km/h (PA_8) represent moderate and vigorous physical activity.

Table 5.3 Mean (M) and standard deviation (SD) values for habitual physical activity, including total time and count per minute of PA and also intensity breakdown of time spent at PA_4, PA_6, PA_8

	All		Girls		Boys		
Overall Physical Activity	**144**		**85**		**59**		***P***
	M	**SD**	**M**	**SD**	**M**	**SD**	
PA_{Total} (min)	239.96	39.54	233.18	34.59	249.74	44.24	*
Total Counts (cnts.min^{-1})◊	554.91	137.92	518.72	120.87	606.79	145.11	**
PA_4 (min)	81.44	28.12	78.93	27.35	85.05	29.05	
PA_8 (min)	7.80	7.01	5.73	4.53	10.77	8.73	**

◊ n= 146, girls n=86, boys n=60

* Sex differences P<0.05, ** P<0.001

The total time spent in physical activity per day equivalent to and above 4km/h was over the current recommendation of 60 minutes per day (Strong *et al.*, 2005) for both girls and boys. Further analysis of time-spent in physical activity at PA_4 showed 70.5% of the group achieved the 60min per day recommendation, with nearly one third (29.5% or 43/146) failing to meet this requirement.. Almost 35% of children meeting the 60-min recommendation participated in physical activity for between 60 min and 90 min per day. The highest activity threshold for time spent in physical activity at PA_4 was set over 90 minutes per day. Thirty-six percent of children participated in over 90min of daily physical activity.

5.3.6 Relationship between physical activity and health related variables

Positive correlations between PA (PA_{total}, PA_4 and PA_8) and total body BMC (with PA_8 only) and BMD were found in the pooled sample (n=127), as were negative correlations with percent body fat and percent trunk fat (Table 5.4).

Table 5.4 Correlation (r) of mean time spent in total physical activity (volume) and intensity with C-R fitness, bone health and body composition variables.

n=127	**Total PA** (M=240.14min)	**PA >4km** (M=82.13min)	**PA >8km** (M=7.67min)
TB BMC (g)	0.05	0.11	0.20 *
TB BMD (g.m-2)	0.20 *	0.19 *	0.20 *
Percent BF (%)	-0.19 *	-0.20 *	-0.26 *
Percent Trunk Fat (%)	-0.15	-0.20	-0.22

* $P<0.05$

5.3.7 Dose-response relationships: *Bone, body composition and physical activity.*

To examine at the dose-response relationship between bone, body composition and physical activity, the data was split regarding time spent in PA above or equal to 4 km/h (PA_4). The thresholds being; less than 60 minutes (<60min) of PA per day (n=43; girls n=26, boys n=17), as this is the current PA guideline for PA in the UK; and over or equal to 60 min (≥60 min) of PA (n=103; girls n= 60, boys n=43). The ≥60 min threshold was further split into over 60min but under 90 minutes (≥60 <90min) of PA per day (n=50; girls n=36, boys n=14), as 90 minutes was been suggested as a more realistic threshold for PA guideline according to Anderson *et al* (2006) with the EYHS findings, and over 90mintes per day (≥90min) of PA (n=53; girls =24, boys =29).

5.3.7.i Time spent in PA: <60 min per day$\geq PA_4$

The children who participated in less than 60 min who were also classified as overweight by BMI (Chinn and Rona, 2004) and had significantly higher percent body fat (M= 29.7%; $P<0.001$) and fat mass ($P=0.032$) compared to children who participated in ≥60min PA per day (Figure 5.1). Correlation analysis uncovered no evidence of relationship between time spent in PA or intensity of PA and bone health variables but did show a significant correlation coefficient between time spent in PA_{Total} and lean mass (r=0.35, P=0.04). Mean time spent in PA_4 and PA_8 was 51.6 min and 4.7 min respectively.

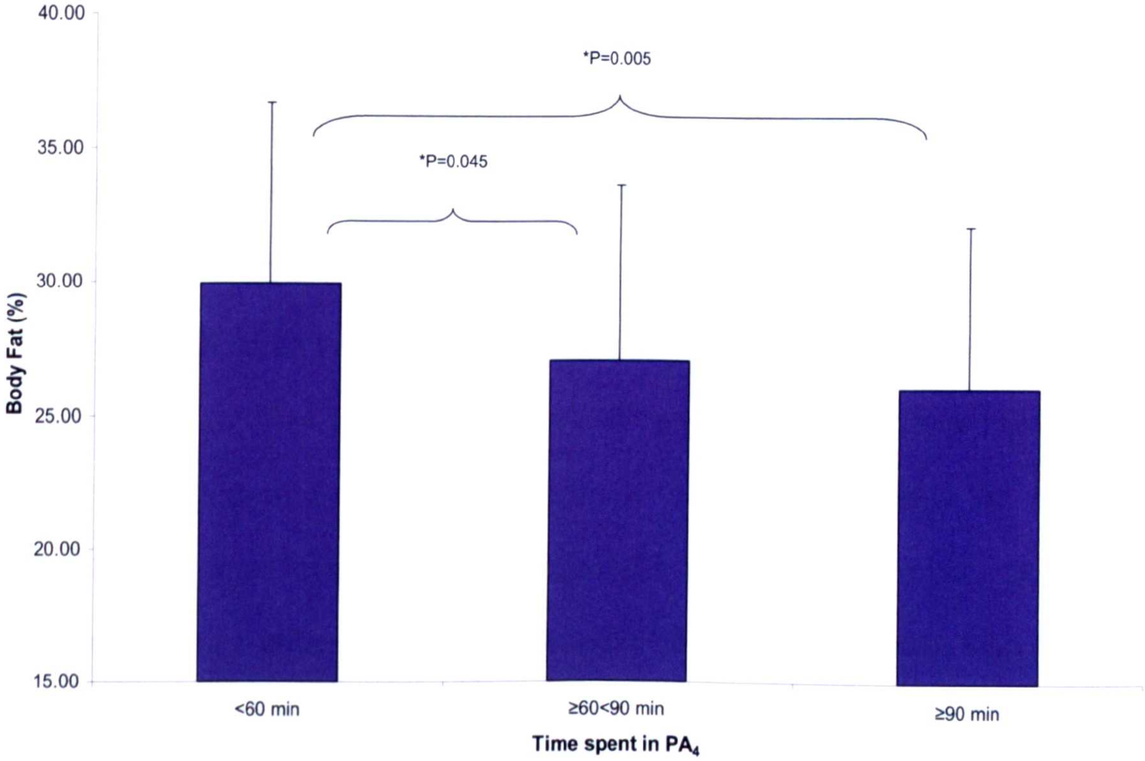


Figure 5.1 Percent body fat by time spent in PA_4 tertiles of less than 60min, 60-90min and over 90 min.

5.3.7.ii Time spent in PA: ≥60min per day at ≥PA_4

Negative correlations between time spent at PA_8 (8.8 min) percent body fat and percent trunk fat for both total PA_{Total} and PA_8 (Table 5.4) were observed when only children participating in PA for more than 60 min were analysed. No significant correlations were found between physical activity and bone mineral variables in the mixed sample.

5.3.7.iii ≥60<90 min per day at ≥PA_4

Of this sub-sample of data, results found that children in this group had significantly lower percent body fat (F=4.12, P=0.04) compared to children who participated in PA <60min per day. A positive correlation between time spent in PA_8 and BMD_{TB} (r=0.32, P=0.03) was found but no other significant correlations.

5.3.7.iv ≥90 min per day at ≥PA_4

Children who participated in PA_4 for over 90 min per day spent on average 112.9±16.7 min in PA_4 and 10.5±9.4 min in PA_8 and possessed 26.2±6% body fat. Children had significantly lower percent body fat (F=8.46, P=0.005) and fat mass (F=4.17, P=0.04) than children participated in less than 60 min per day (Figure 5.1), and significantly lower percent body fat (F=5.17, P=0.02) than all children who participated in less than 90 min per day.

Correlations coefficient revealed stronger negative relationship with body fat (Table 5.5), particularly with more vigorous activity (PA_8). Total body BMC was significantly correlated with total PA (r=0.32; P=0.03) in the whole group.

Table 5.5 Significant correlations (r) between body fat indices and time spent in physical activity (total and at PA_4, PA_6 and PA_8 intensities).

		PA_{Total}	PA_4	PA_8
Fat Mass (g)	**<60 min**	ns	ns	ns
	≥60<90 min	-0.22	ns	ns
	≥90 min	ns	ns	-0.31
Body Fat (%)	**<60 min**	ns	ns	ns
	≥60<90 min	-0.24	ns	-0.29
	≥90 min	ns	ns	-0.43
Trunk Fat (%)	**<60 min**	ns	ns	ns
	≥60<90 min	-0.21	ns	-0.25
	≥90 min	ns	ns	-0.36

ns = non significant P>0.05

5.3.8 Determinants of BMC and BMD: Relationship between body composition and bone mineral content and density

We observed significant positive correlations between total body lean mass, leg lean mass and bone mineral content and density (TB, FN and LS) in the sample

Table 5.6). No significant correlations were found with time spent in total PA, PA_4 or PA_8.

Table 5.6 Partial correlation of lean mass and bone mineral content and density of total body, femoral neck and lumbar spine of boys and girls

	All			
	LM (g)		**LM_{LEG} (g)**	
BMC_{TB} (g)	0.69	**	0.67	**
BMD_{TB} (g.m^{-2})	0.52	**	0.49	**
BMC_{FN} (g)	0.73	**	0.71	**
BMD_{FN} (g.m^{-2})	0.40	**	0.38	**
BMC_{LS} (g)	0.67	**	0.64	**
BMD_{LS} (g.m^{-2})	0.39	**	0.37	**

* $P<0.05$, ** $P<0.01$

Regression analysis confirmed that lean mass was the strongest predictor of bone mineral content and density in total body, femoral neck and lumbar spine analysis. Lean mass accounted for 49% of the variability in BMD_{TB} ($F=128.7$, $\beta=0.70$, $P<0.001$), 52% in BMC_{FN} ($F=145.9$, $\beta=0.73$, $P<0.001$) and 46% in BMC_{LS} ($F=114.6$, $\beta=0.68$, $P<0.001$). In BMD, despite being the strongest predictor, lean mass only accounted for 28% of variance in BMD_{TB} ($F=53.5$, $\beta=0.53$ and $P<0.001$) and 15% in both BMD_{FN} ($F=24.1$, $\beta=0.40$, $P<0.001$) and BMD_{LS} ($F=24.4$, $\beta=0.40$, $P<0.001$) regions. Maturity offset (MO) status accounted for an additional 1-5% of the variability in $BMC_{TB,FN,\ LS,}$ and had no additional predictive effect on $BMD_{TB,FN,\ LS.}$ When lean mass was factored out of the analysis, no physical activity variables were significant as predictor variables.

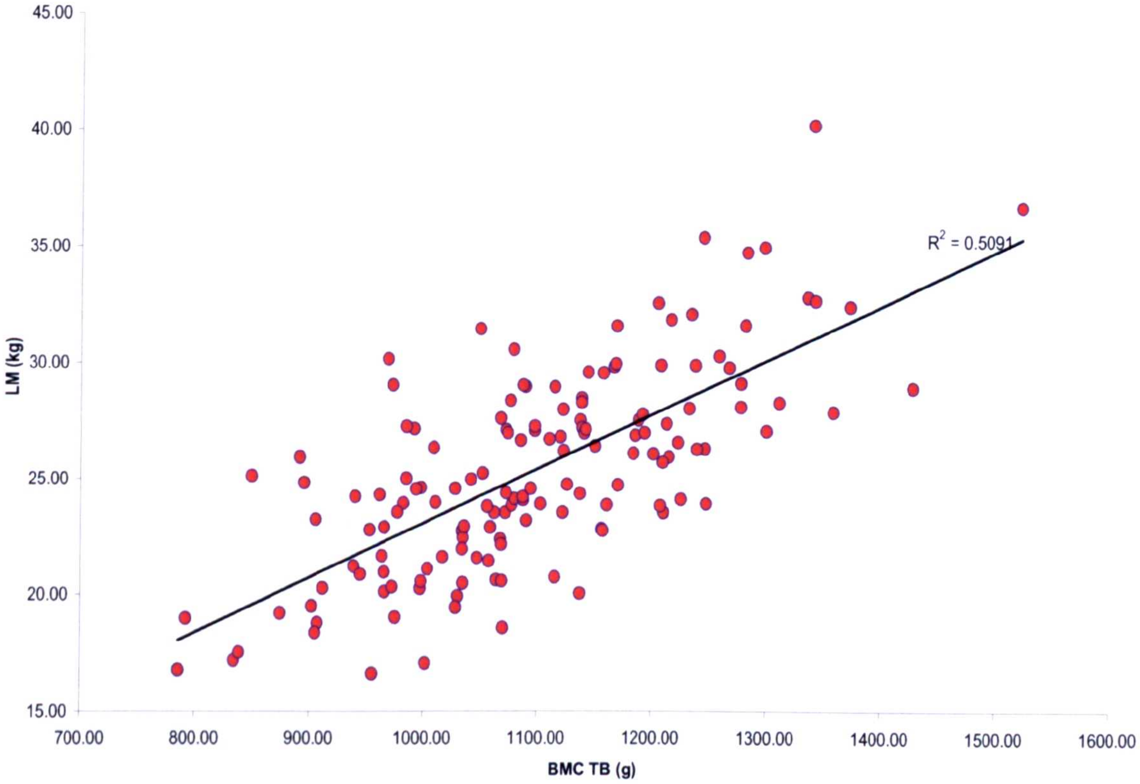


Figure 5.2 Correlation between Total Lean Mass (g) and Total Body Bone Mineral Content (g) (BMCTB) of pooled sample

5.3.9 Relationship between field-based measures and DXA measures in body fat assessment

Significant correlations were found between the skin-fold assessment of body fat (total and percent) and DXA assessment. Total body fat was strongly correlated with the ∑4 (r=0.90, P<0.001), ∑7 (r=0.89, P<0.001) and the ∑8 (r=0.87, P<0.001) skin-folds. Percent body fat also correlated highly with all sum of skin-fold measures (∑4 r=0.87, P<0.05), ∑7 (r=0.87, P<0.01) and the ∑8 (r=0.86, P<0.01). There were no significant differences between girls and boys (P>0.05). BMI produced the next strongest correlation with DXA derived body fat mass (r=0.86, P<0.001). Waist circumference was also significantly related to DXA fat mass and percent body fat ($r=0.77$, $p<0.01$) as was waist-to-hip ratio ($r=0.16$, $p=0.05$).

5.4 Discussion

The purpose of this small scale correlational study was to explore relationships between bone mineral status, body composition and physical activity. The results indicated that over one third of the children in the sample were classified by BMI as overweight (Chin and Rona, 2004). The mean time-spent in physical activity of intensity above or equal to 4km/h (PA4) exceeded the current children's physical activity guideline for health marker of 60 min per day (CMO, 2007). Further examination however found that a considerable proportion of children (30%) failed to meet this guideline

The positive correlations between PA and bone, specifically BMC_{TB} and PA_8 indicate the influence of volume and intensity of physical activity on bone mineral accrual, which supported previous work by Hasselstrom *et al.* (2007), Janz *et al* (2006) and Greene *et al* (2005).

5.4.2 Dose-response relationships

Physical activity was negatively correlated with indices of body fat, indicating those children who are more active are likely to have lower body fat. The relationship between body fat and time spent in PA has been both supported (Ball *et al.*, 2001., Abbot and Davies, 2004) and refuted (Al-Nakeed *et al.*, 2007) in the literature. The BMI of the inactive children (participated <60 min) classified them as overweight (Chinn and Rona, 2004), they also had significantly higher DXA-derived percent body fat ($P<0.001$) compared to children who participated in over 60 min per day. However, there were no relationships between PA bone and body fat within this low activity group. Dose-response relationships only emerged when we examined data from children who participated in more than 60 min, where time spent in PA_{total} and PA_8 (approx 9min per day) had a negative relationship with percent body fat. Therefore duration of time spent in PA_{total} and specifically time spent at higher intensities (PA_8) was negively related to body fat status. Just over one third of children participated in over 90 min of PA_4 per day, Anderson *et al.* (2006) concluded that 90 min of PA is the minimum requirement to protect against prevalence of clustered risk factors, but specified that for 9 year old children, 116 min of PA is necessary. The results in this study highlight a graded negative association between time spent in PA and percent body fat, which is supportive of the Andersen *et al.* (2006) findings with risk factor clustering. The mean time spent in PA for the over-90 min group was 112 minutes which is close to the 116min guideline proposed by Andersen *et al.*(2006).

Children who participated in over 60 min per day at PA_4 were significantly less fat than the children participating in a volume of <60 min per day. No significant correlation was found between volume or intensity of PA and body fat when the 60-90 subgroup was analysed. The negative relationship with fat only materialised when the over 90min per day was analysed, showing a stronger correlation with PA_8, indicating that over 90 minutes of PA_4 per day may be more beneficial to body fat than over 60 min, however further investigation would be required to confirm this.

No relationships between time spent in PA and bone mineral were evident when examining the over-60 min per day data set. Relationships only emerged when time spent in PA was further split into 60-90 minutes, and >90min sub categories. In the 60-90 min data set, time spent in vigorous activity (PA_8 = 7.7 min, was significantly related between BMD_{TB}, the same correlation coefficient was found in the over-90 min data set, where 10.54min were spent in PA_8. Thus, indicating that vigorous activity for over 7.7 minutes per day may be sufficient to promote bone mineral accrual.

Given that at in the over-90 min group, positive relationships between total PA and bone were specifically apparent in girls ($BMC_{TB,FN}$ and $BMD_{TB,FN}$) this may suggest that bone accrual in the total body and at the femoral neck may benefit more from a higher volume (over 10 min) of high-intensity activity (PA8) , but this duration, particularly regarding femoral neck bone mineral accrual, may not be sufficient for boys.

The determinants of bone mineral were explored to find the best predictor of BMC and BMD. Lean mass emerged as the strongest predictor of BMC and BMD. The "mechanostat" theory stipulates that strain caused by forces applied to the bone through gravity and locomotion through muscle (lean mass) contraction has an osteogenic effect (French *et al.*, 2000., Janz *et al.*, 2004). Rauch *et al.* (2004) confirmed the mechnaostat theory; that muscle development proceeds bone development during pubertal growth. Therefore if lean mass (muscle) is increased through physical activity, the contractile forces placed on the bone by the muscle is potentially greater; therefore increased lean mass indirectly enhances bone mineral properties (Rauch *et al.*, 2004; Tobias *et al.*, 2007). Evidence that lean mass is the strongest determinant of bone mineral density is supported throughout the literature (Uusi-Rasi *et al.*, 1997; Crabtree *et al.*, 2004; Vicente-Rodriguz *et al.*, 2005) and by the present study, but there is insufficient evidence to support PA as the stimulus variable as a causal factor.

5.4.3 Best field method of body fat assessment.

Dual-energy X-ray Absorptiometry is considered the reference method for field based measures such as waist circumference, waist-to-hip ratio, BMI and skin-fold assessment in validation studies. The sum of 4 skin-fold measures had the strongest correlation with DXA derived fat mass, with BMI as the next strongest. The ∑4 skin-fold data concur with the DXA estimated body fat output concluding that girls were fatter than boys. The BMI, however, classifies boys as overweight and girls as not-overweight, this disagreement could be a consequence of the BMI thresholds used (Chinn & Rona, 2004) but it may also add to the uncertainty surrounding the accuracy of BMI as a measure of adiposity. Controversy currently surrounds the use of BMI as a measure of overweight and obesity in children because of its insensitivity to body composition and variations in tempo of growth between children.

The correlation findings support the use of the simple field-based procedures such as BMI as an estimate measure of adiposity, which is supported in current literature (Savva *et al.*, 2000; Andersen 2008), the authors however suggested such methods should be used with caution. The mean BMI in this study was not representative of the mean adiposity; because according to BMI, a higher proportion of boys were overweight and obese compared to girls, which is contrary to the DXA reports.

5.4.4 Limitations

The observations of the present correlational study provided an insight in to relationships between the variables to be examined in study 3. The small scale size and nature of the study however limits any direct causal associations. The accuracy of maturity status estimated the maturity offset calculation (Mirwald *et al.,* 2002) may be limited. Mirwald *et al.* (2002) stated that the accuracy of the equation is reduced significantly if the child is more than 2 years to PHV, the subjects in this study are 3 years to PHV.

5.5 Conclusion

This small scale correlational study shows that the children involved in the A-CLASS intervention project are participating in recommended levels of activity. However, despite the children achieving the PA recommendation guideline, body fat measures indicate that the children fall between the 85th-95% percentile for overweight and obesity (McCarthy *et al.*, 2006) and bone mineral density status also falls below reference values describes by Zanchetta *et al.* (1995), and Van der Sluis (2005). The significant relationship between physical activity (volume and intensity) bone mineral and body fat (negative) highlight the dose-response relationship and portrays the importance of the high volume (over 90min per day) and high intensity physical activity (over 10min per day) as a precursor to low body fat and high bone mineral status in children.

Chapter

6

Study 3: 12-month Intervention study

The effects of a 12-month physical activity programme of high intensity exercise, fundamental movement skill-based exercise and a lifestyle-based intervention on bone health, body composition, physical activity and cardio-respiratory fitness in primary school children: The A-CLASS Project.

6.0: Study 3; 12-month A-CLASS Intervention study

The effects of a 12-month physical activity programme of high intensity exercise, fundamental movement skill-based exercise and a lifestyle-based intervention on bone health, body composition and physical activity fitness in primary school children: The A-CLASS Project.

Aspects of this work within this chapter have been presented at the VIth International Conference on Sport, Leisure and Ergonmoics 2007 and the Institute of Health Research Conference 2008.

6.1 Introduction

6.1.1 Current health status

Epidemiological data and cross sectional studies discussed in chapter 2 provide a stark outlook on the health of children. The need for a practical intervention to promote positive changes in bone mineral and body composition through physical activity/exercise is required to halt the year on year rise in obesity (DoH, 2005) and help reduce the prevalence of health risk factors in children.

6.1.2 Exercise interventions

The relationships between physical activity, bone health and body composition has been previously discussed (Chapter 2 and Chapter 5), but there is limited intervention research that use objective measures as means to evaluate the effectiveness of such interventions. Furthermore, few studies attempt to assess the effect of more than one intervention (lifestyle/education and exercise), those that do (Gutin *et al.*, 2002; McMurray *et al.*, 2002) assess obese populations. Multi-disciplinary interventions (Zahner *et al.*, 2002; Knopfli *et al.*, 2008) often fail to assess the individual effect of each treatment, and only a small number of studies assess multiple outcome variables (Gutin *et al.*, 1999, Zahner *et al.*, 2002). Furthermore, a good proportion of intervention studies could not feasibly be integrated into a children's everyday lives for a prolonged duration, particularly evident in bone health research (Fuchs *et al.*, 2001; McKelvie *et al.*, 2001; 2002, McKay *et al.*, 2005).

6.1.3 Rationale

With the rise in childhood obesity and reduction in PA, intervention research is required to investigate the effectiveness of different exercise programmes that promotes positive changes in bone health and body composition in children.

6.1.4 Aims

This study aims to evaluate the effect of 3 different exercise interventions over 12 months (ran simultaneous to each other); on bone mineral accrual (BMC and BMD) and body composition (Fat mass, % body fat) in 9-11 year old children.

6.2 Methods

6.2.1 Participants and settings

Sixteen schools were invited to participate in a longitudinal research study; The A-CLASS Project (Consort statement, Appendix C:2). The schools were chosen from the local area ward, all schools were similar in school size, facilities and had available indoor space to house the intervention. All schools were located in areas classified by the Index of Multiple Deprivation (2004) as deprived (IMD > 40). This index is based on income, unemployment, housing, health and education, access to services, telecommunications and crime. Representatives from each school attended an A-CLASS project information seminar held at the university to learn more about the project. Eight schools were then randomly selected to participate in the project and further randomly allocated into groups. Eight was the feasible number of schools we could manage given the resources and staffing available. The randomisation by groups followed a two-group-per-condition design. The project would involve children in Year 5 (aged 9-10) and would follow the children into year 6. Parental and child informed consent and assent respectively was sought for interest in participation in the study. Medical questionnaires were also distributed to all children interested in the study. All year 5 children in each school were assessed for stature and body mass in order to calculate Body Mass Index (kg/m^2). Body Mass Index was used as simple guide to target the children who were overweight or may be nearing overweight according to BMI cut-off thresholds stipulated by Chinn and Rona (2004). Generally, 20-25 children with the highest BMI within each school who were free from the presence of chronic disease, metabolic disorders, and prescribed medications including steroids inhaled by asthma sufferers were invited to participate in the project. The number varied slightly between groups according to the number of children excluded for medical reasons and also to accommodate for more high-BMI children in one school compared to another. In the two-school-per-condition design, each condition contained the children with highest BMI scores from the available population (2 schools). Each treatment group included approximately 40-45 children. Ethical permission for the A-CLASS project was obtained from the institution's Research Ethics Committee.

6.2.2 Instruments and procedures

6.2.2.i Data collection

All measures were taken before intervention commenced (baseline, 0 months), during intervention program (mid-Intervention, 9 months) before the 6–week school holiday break, and after the intervention (post-intervention, 12 months).

6.2.2.ii Anthropometry

In addition to the anthropometric measures detailed in Chapter 3, multiple skin-fold measures were taken to account for morphological and fat distribution changes that may occur during the intervention (Chapter 5, Methods).

6.2.2.iii. Assessment of Maturation

Maturation was estimated using maturity offset calculation (Mirwald et al 2002) to estimate the number of years from peak height velocity (Chapter 5.2.2).

6.2.2.iv Densitometry - DXA

Coefficient of Variance (CV) expresses the precision error and was calculated to validate the accuracy of inter-reliability of scan interpretation. Each scan (Total Body, Femoral Neck and Lumbar Spine) was analysed 3 times at each test point (0-9-12 months). The CV was calculated by

$$\mathbf{CV}= SD\ (1,2,3)\ /\ \bar{x}\ (1,2,3) * 100$$

or

$$\mathbf{CV}= \frac{SD(1,2,3)}{\bar{x}\ (1,2,3)}\ .\chi\ 100$$

The coefficient of variation (CV) (mean 0, 9 and 12 month measures) for the repeated measurements were BMC_{TB}, 0.17%, BMD_{TB}, 0.13%, BMC_{FN}, 1.23%, BMD_{FN}, 0.47%, BMC_{LS}, 0.65%, BMD_{LS}, 0.42%. The calibration for body composition variables was performed weekly using a step phantom supplied by manufacturers. The CV for repeated body composition measures were FM, 0.24%, %BF, 0.25%.

6.2.2.v Physical activity

In addition to the methodological details described in Chapter 3 and 4, individual calibration was performed to increase the accuracy of physical activity assessment. In terms of time spent in physical activity, individual calibration was acquired from accelerometer data recorded from treadmill walking and running obtained from a $\dot{V}O_{2Peak}$ assessment (not reported). Percent of $\dot{V}O_{2Peak}$ and treadmill speeds were used to quantify the intensity of activity in counts per epoch for each child. These counts were subsequently used to calculate the time spent in equivalent speeds of locomotion during habitual physical activity. With focus of different intensities; 4km/h was equivalent to 40-60% $\dot{V}O_{2Peak}$ which is classified as moderate intensity activity (Trueth *et al*, 2005). Intensity at 8km/h or above was equivalent to over 60% $\dot{V}O_{2Peak}$, which is classified as vigorous activity. At treadmill speeds above 9km/h a plateau effect occurs with accelerometer counts. Thus all physical activity over the 8km/hr intensity was classified as vigorous. The total time-spent in physical activity of intensity equivalent to 4km/h or greater per day was used for time spent in MVPA. Moderate-

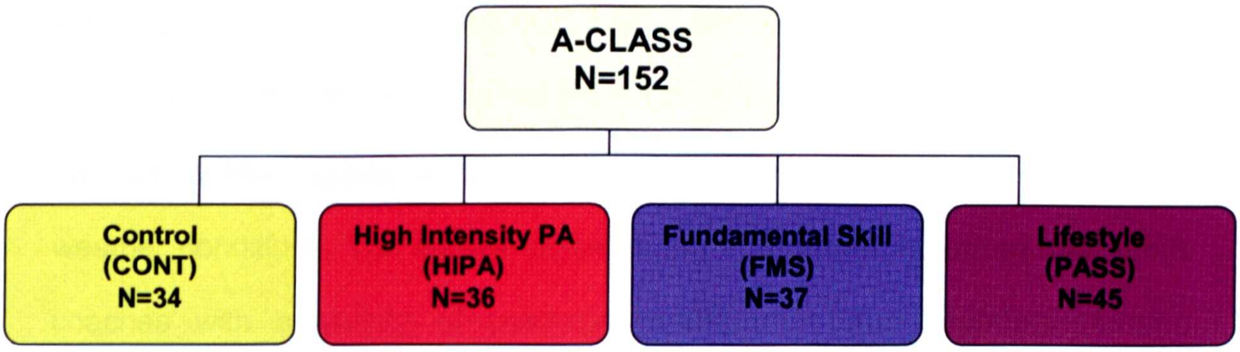
Vigorous PA and VPA data were averaged by the number of days used for recording (3 days) and used as an estimate of weekly activity.

6.2.3 Intervention Design

6.2.3.i One-year Intervention design

Physical activity interventions were conducted over one school year (September/October 2007 – November/Dec 2008, Figure 6.1). The 12 month period matched the school calendar and was timed to minimise loss of effect over school holiday periods. Each school was randomly allocated to one of four groups (picked out of a hat) to reduce risk of contamination effects across the trial. Groups included 1: a high intensity physical activity (HIPA) group, 2: a fundamental movement skill (FMS) group, 3: a physical activity signposting (PASS) group and 4: a control group.

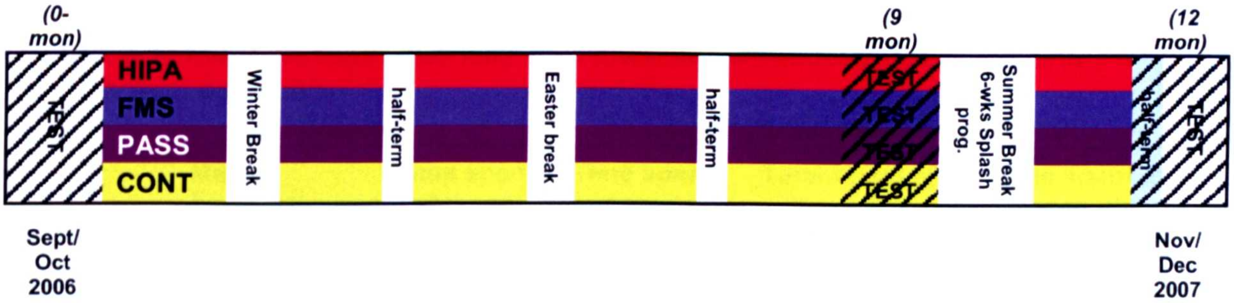
Figure 6.1. The group design of study 3.



Each intervention group included children from 2 schools. In a two-group-per-condition design, the equivalence of groups at baseline is not secure (Consort statement Appendix C:2). To address this threat to validity, the schools selected were as similar as possible for the distribution of age, mass and socio-economic status.

Periods of testing were held before the intervention (0-months) to record baseline values (Study 2), at mid intervention (9-months) which was prior to the 6-week summer break and post-intervention 12 months (Figure 6.2).

Figure 6.2 Illustration of the intervention design over 12 months, intervention groups, test periods and school breaks.



6.2.3.ii High Intensity Physical Activity (HIPA)

The HIPA programme is based upon the STEX programme trialed in the feasibility study (Study 1) Children attended after-school club sessions of high-intensity vigorous activity (duration 1 hour) twice weekly for a 24-week period in school term time. All sessions were located at the intervention school, sports-hall and outdoor space were used depending on availability of facilities and weather conditions. The activity sessions were delivered by trained multi-skills coaches with a variety of coaching qualifications and coaching children experience. Coaches were not blinded from the study design. The sessions included a combination high intensity activities such as playground-style games and circuit training activities (Appendix D:1). The intensity target was to maintain an average heart rate of above 70% of the age-predicted maximum heart rate (~145 beats. min^{-1}) for the duration to confirm the vigorous nature of the sessions. The mean heart rate (bpm) for HIPA sessions and the mean time spent at each level of intensity are shown in table 6.1. Three children were randomly selected to wear heart rate monitors (Polar Team System Interface) in least one session per week, heart rate data was analysed by Polar Precision Performance software (Polar Electro Oy, Kempele, Finland). Children were awarded a point for every session attended; rewards were given to children to maintain motivation and complience to intervention and thus reduce drop out. The rewards system is described in more detail later in this chapter.

Table 6.1. Mean session intensity and intensity breakdown for HIPA and FMS intervention sessions

	Session			**Intensity breakdown during session**		
	Mean heart rate		**Time spent at mean HR**	**Time spent at mean 75%HRmax**	**Time spent at mean 50-74.9%HRmax**	**Time spent at mean 25-49.9%HRmax**
	M (bpm)	*SD*	M (mm:ss)	M (mm:ss)	M (mm:ss)	M (mm:ss)
HIPA	150	*25*	51:47	14:25	19:35	15:09
FMS	141	*24*	54:45	09:06	21:01	21:12

6.2.3.iii Fundamental Movement Skill (FMS)

The fundamental movement skill (FMS) programme was introduced into the intervention following the feasibility study (Study 1) to assess the effect of skill based structured exercise. The FMS intervention consisted of a twice-weekly after-school club, located within the intervention school. Eight fundamental movement skills were focussed upon, including, locomotive skills; hop, vertical jump, dodge and sprint run and also object control skills, kick, catch, overhand throw and strike. Each one-hour session focused on improving two fundamental movement skills, all skills were taught in equal quantities. Appendix D:2 shows examples of FMS sessions. Table 6.1 displays the intensity of the sessions. Multi-skill circuits involving activity stations to improve all the skills were periodically introduced into the sessions. Each session was delivered by experienced coaches who held several sports coaching qualifications and had attended Sports Coach UK workshops on delivering multi-skill clubs prior to the intervention programme. The intervention programme was planned using activity resources designed by the Youth Sports Trust (Hanford, Haskins, Hawkins, Haydn-Davies, Morley, & Stevenson, 2005), with each session designed to maximise participation and enjoyment, consisting of a variety of games, drills and self-learning activities offering numerous opportunities for practice. Skill components were taught to the children using simple learning cues (in kicking "eyes on the ball" was used to try to get the children to keep their eyes on the ball during the kicking action), and skill questions were used to develop purposeful feedback (for example - where did your throwing arm finish when you released the ball?). Children were awarded a point for every session attended; rewards were given to children when a required number of points were achieved.

6.2.3.iv Physical Activity signposting scheme: (PASS)

After poor compliance to PASS in study 1, the methods of delievery was changed to involve a PASS officer who visited the children in school each week in 6 weekly blocks to set them an activity "mission". The programme was still based on the theoretical behaviour change model of the social cognitive theory (Bandura, 1986). Each mission suggests a task as a prompt to participate in physical activity during the week and decrease sedentary activity (Hepples and Stratton, 2007). This intervention aims to encourage and incorporate physical activity (no specific intensity) into their lifestyle using an intervention mapping approach. The missions were based on a combination of both theories, incorporating the benefits of physical activity including enhancement of confidence and skill, self-control, goal setting, active prompts and information on activity opportunities in different environmental contexts. A description and examples of missions can be found in Appendix D:3). Sentiments about completed missions were also discussed during the weekly visit from the PASS officer. Children received a sticker on a wall chart for returning the mission; children were rewarded with prizes if all missions were returned in each block. A compliance criterion of 75% attendance was required for children to be included in the study for data to be valid. In addition to the "missions", pedometers were given to the children as a promotional tool for the entirety of the project for the self-monitoring process of activity.

6.2.3.v Control (CONT)

Children in the control group received no form of intervention. They only received information on physical activity (BHF information pack) and health given in the information pack (given to all groups) at baseline testing.

6.2.3.vi Six-week school summer break period: SPLASH Programme

At the commencement of the A-CLASS project, the use of school facilities to continue intervention sessions over the school summer break were deem feasible. Due to unforeseen logistical difficulties and school compliance, this did not materialise. Local council sport and leisure facilities were also unavailable for private use during this period. The local authority however organise a summer activity program called SPLASH, available in every sport and leisure facility in the area and is free to children aged 7-19 years. The SPLASH programme offered a wide range of organised activities on weekdays from 10.00 to 16.00 hours. Given its accessibility, the SPLASH programme was promoted to the children involved in the HIPA, FMS and PASS groups. The children in the control group were able to attend SPLASH but attendance was not deliberately promoted. The HIPA, FMS and PASS children were given A-CLASS–SPLASH "passports" designed by the A-CLASS team to monitor attendance at SPLASH sessions. All A-CLASS–SPLASH material designed for the summer program was in agreement with the SPLASH co-ordinator. Children would present the passport at the SPLASH session and get it signed by the session leader to confirm activity and attendance. Children were given information packs including directory of SPLASH centres with contact information, a passport and an instruction and information sheet for parents. Passports were collected by the A-CLASS coaches (n=4) at the activity sessions after the summer break. If attendance at SPLASH contributed to approximately 2 hours of vigorous activity each week, children were awarded a reward point by A-CLASS coaches, contributed to the reward scheme.

6.2.3.vii Rewards Scheme

All children involved in the A-CLASS project received rewards throughout the study. Children in the exercise-based intervention groups (HIPA, FMS) received rewards for attending required number of sessions (Table 6.2). Children in the PASS groups received rewards for completing and returning all the missions in each 6-week block (Table 6.3). Rewards were also given as incentives for physical activity monitoring compliance in the latter part of the study. All control children received rewards for attending testing sessions at university (baseline and post-intervention) and for physical activity monitoring (PAM) compliance (Table 6.4). All children received A-CLASS certificates to signify completion and participation in the project. Schools also received a certificate.

Table 6.2 The distribution of rewards for attendance to activity sessions and physical activity monitoring for the HIPA and FMS groups.

	B-line testing	B-line PAM	10 sessions	25 sessions	40 sessions	Mid-Test	Mid PAM	60 sessions	Post-test	Post PAM
HIPA	–	–	A-CLASS T-Shirt	Water bottle	Pedometer	–	–	A-CLASS Baseball Cap & music CD	Frisbee & beach ball	A-CLASS yoyo
FMS	–	–	A-CLASS T-Shirt	Water bottle	Pedometer	–	–	A-CLASS Baseball Cap & music CD	Frisbee & beach ball	A-CLASS yoyo

B-line = baseline
PAM= physical activity monitoring

Table 6.3 The distribution of rewards for completion of missions and physical activity monitoring for the PASS group

	B-line test	B-line PAM	Start PASS	1st Block	2nd Block	3rd Block	Mid-Test	Mid PAM	4th Block	Post-test	Post PAM
PASS	–	–	Pedometer	A-CLASS T-Shirt	Water bottle	A-CLASS Baseball Cap	–	–	A-CLASS music CD	Frisbee & beach ball	A-CLASS yoyo

Table 6.4 The distribution of rewards for the CONT group for attending testing and completing physical activity monitoring.

	B-line test	B-line PAM	Post-test	Post PAM
CONT	A-CLASS T-Shirt	Water bottle	Frisbee & beach ball	A-CLASS yoyo

6.2.4 Statistical analysis

Means (M) and standard deviation (SD) for all variables were calculated. The statistical package SPSS for windows version 14 (SPSS Inc. Chicago, IL) was used to conduct data analysis. All results were considered to be significant when P<0.05. Baseline differences between sex and between groups were tested for significance using a one-way ANOVA with pair-wise comparisons. Change (Δ) scores were calculated to describe variable change between baseline, mid and post intervention. Baseline to mid-intervention change ('Mid' minus 'baseline') is described as 9-month change. Baseline to post intervention ('Post' minus 'baseline') describes the 12-month change. Change between mid and post test explains the 3-month change which include the 6-week break from the intervention during the school holiday period.

Analysis of covariance was conducted to compare the effectiveness of the intervention over 9 and 12 months. The change scores for each variable over 9 and 12 month change from baseline were used in this analysis. The independent variable was the type of intervention group (HIPA, PASS, FMS vs CONT), with the dependent variable as the variable change score ('post' or 'mid' minus baseline). The baseline value for the variable was used as the covariate in this analysis, to control for any imbalances at baseline (Vickers and Altman, 2001) and additional covariates were included to adjust for differences in lean mass or maturation. Maturity offset scores differed considerably between groups over the 12-month intervention, particularly at mid (*P*=0.005) and post intervention (*P*=0.007) time points. The use of maturity indicators as a covariate in paediatric data analysis literature is also supported in the literature (McKelvie *et al.*, 2003; Dencker *et al.*, 2006; Ortega *et al.*, 2007; etc). Maturity offset change was used as a covariate for anthropometric data, bone and body composition analysis.

In the absence of robust evidence confirming appropriate covariates to use in bone intervention studies, the choice of covariates in this study were drawn from a combination of theory-led and data-led decisions.

Analysis of variance for bone mineral change was adjusted using lean mass change as a covariate in addition to the baseline variable. During exploratory analysis of bone data, maturity offset and lean mass were both considered as covariates as, maturity of set measures maturational change and LM differs substantially between groups. Initially only the baseline variable was used as a covariate. In the example of BMC_{FN}, all groups showed significant change compared to the CONT over 12 months. Maturity offset was added as a covariate which was significant between subject effects ($P<0.01$) and caused the size of he effect to reduce. Lean mass was further added as a covariate ($P<0.01$) causing the size of the effect to increase but also resulted in maturity offset being not significant. This infers that maturity offset and LM have a similar effect on the intervention data and may be collinear. The correlation between change in lean mass and change in maturity offset was significant ($r=0.51$; $P<0.01$) showing that they effect a substantial proportion of the variance, but LM may have a stronger influence than maturity offset. Finally, only lean mass and the baseline variable (BMC_{FN}) were introduced as covariates in to the ANCOVA. Significant change was observed in all groups compare to CONT over time, but the size of effect is dampened because of the use of LM as a covariate. Regardless of this, in this example the ANCOVA showed that the effect of the intervention was demonstrated by significant change in BMC_{FN} independent of changes of LM mass between groups. The use of LM as a covariate is supported by its correlation of maturity index inferring that changes in maturity offset may be similar to changes in LM. The analysis will therefore demonstrate the size of the intervention effect without and with maturity offset as a covariate to demonstrate the effect dependent and independent of maturity offset change.

6.2.4.i Minimum clinically importance difference (MCID)

Effects were evaluated for clinical significance (Batterham and Hopkins, 2006) by pre-specifying the minimum clinically importance difference (MCID). In the absence of a robust clinical anchor, the MCID is defined conventionally using a distribution-based method as a Cohen's *d* (standardised difference in the change scores between groups) of 0.2 between-subject standard deviations (Cohen, 1988). The SD of the pooled baseline scores was used for this purpose, as the post-test SD may be inflated by individual differences in responses to the intervention. The MCID was interpreted as 'benefit' or 'harm' according to the direction of the effect on the intervention for a given variable. The probability (percent chances) that the true population effect is beneficial (>MCID), trivial (within ± the MCID), or harmful (> MCID in the opposite direction) was calculated and interpreted according to the recommendations of Batterham and Hopkins (2006).

6.3 Intervention Results

A total of 152 children participated in the project. The consort statement (Appendix C:2) describes assessment for eligibility, exclusion criteria and also the attrition of participants over the intervention period. All available data were considered in the analysis as intention to treat. Full data sets were completed on 145 children (girls n=86, boys n=59) for baseline to 9-months (pre-to-mid test) analysis, and 144 (girls n=86, boys n=58) for baseline to 12-months (pre-to-post test) analysis (Table 6.5).

6.3.1 Body size and maturation

No significant change in body mass between the ‘CONT’ group and ‘FMS’, ‘HIPA’ or ‘PASS’ intervention groups were observed from the 0-9 month, 0-12 month or 9-12 month data sets (*P*>0.05). A significant change in stature was observed in the ‘PASS’ group from the 0-9 month (95% CI: -0.015 to 0.002; *P*=0.013) and 0-12 month (95% CI: -0.018 to -0.002; *P*=0.01) compared to changes observed by ‘CONT’ group. No significant changes were reported between groups in mean BMI values from in the 0-9 month, 0-12 month or 9-12 month data sets (all *P*>0.05).

The maturity offset units of years to peak height velocity (PHV) decreased across all groups over the 9 and 12 month periods. Adjusted mean maturity offset change scores showed the ‘CONT’ group indicated the least maturational change over 9 (0.36 years) and 12 months (0.61 years). The ‘PASS’ group indicated the most maturational advancement with an adjusted change of 0.55 years over 9 months and 0.87 years PHV over 12 months. ANCOVA analysis found that all intervention groups showed significant maturation change compared to the ‘CONT’ group over 9 months (‘PASS’, 95% CI: -0.26 to - 0.12; *P*<0.01; ‘HIPA’, 95% CI: -0.24 to -0.10; *P*<0.01; ‘FMS’, 95% CI: -0.20 to -0.06; *P*<0.01) and over the 12 month intervention (Figure 6.3).

Table 6.5. Characteristic data from baseline, mid-test (9 months) and post-test (12 months) by intervention group

		Baseline			Mid-test (9-m)			Post-test (12-m)		
	Group	*N*	M	sd	*N*	M	sd	*N*	M	sd
Age (years)	**'CONT'**	*34*	9.84	0.42	*32*	10.34	0.35	*33*	10.77	0.30
	'PASS'	*44*	9.62	0.35	*43*	10.33	0.30	*41*	10.73	0.30
	'HIPA'	*36*	9.66	0.33	*35*	10.36	0.27	*33*	10.72	0.30
	'FMS'	*35*	9.70	0.40	*35*	10.32	0.32	*37*	10.69	0.30
Mass (kg)	**'CONT'**	*34*	35.5	8.81	*32*	37.3	9.25	*33*	40.5	10.28
	'PASS'	*44*	38.9	8.15	*43*	42.2	9.03	*41*	44.8	9.87
	'HIPA'	*36*	39.3	7.35	*35*	42.5	7.96	*33*	45.4	8.33
	'FMS'	*35*	32.5	7.50	*35*	35.1	8.36	*37*	36.7	8.73
Stature (m)	**'CONT'**	*34*	1.39	0.08	*32*	1.42	0.08	*33*	1.44	0.08
	'PASS'	*44*	1.39	0.06	*43*	1.43	0.07	*43*	1.45	0.32
	'HIPA'	*36*	1.40	0.05	*35*	1.44	0.05	*33*	1.46	0.05
	'FMS'	*35*	1.37	0.07	*35*	1.40	0.08	*37*	1.42	0.08
BMI (kg/m^2)	**'CONT'**	*34*	18.14	3.03	*32*	18.42	3.20	*33*	19.26	3.41
	'PASS'	*44*	19.97	3.09	*43*	20.36	3.21	*41*	21.03	3.48
	'HIPA'	*36*	20.06	2.84	*35*	20.29	3.03	*33*	21.07	3.18
	'FMS'	*35*	17.21	2.71	*35*	17.68	2.74	*37*	17.98	2.73
Waist circumference (cm)	**'CONT'**	*33*	61.6	7.61	*32*	61.4	7.62	*33*	64.3	8.14
	'PASS'	*44*	64.7	6.59	*43*	67.5	7.00	*41*	68.3	7.91
	'HIPA'	*36*	65.4	7.02	*35*	66.9	7.47	*33*	68.2	7.86
	'FMS'	*35*	59.3	6.98	*35*	61.2	7.54	*37*	61.9	7.43
Waist to-Hip ratio	**'CONT'**	*33*	0.82	0.05	*32*	0.83	0.05	*33*	0.84	0.06
	'PASS'	*44*	0.83	0.04	*43*	0.85	0.05	*41*	0.83	0.05
	'HIPA'	*36*	0.83	0.04	*35*	0.83	0.05	*33*	0.84	0.05
	'FMS'	*35*	0.84	0.04	*35*	0.84	0.05	*37*	0.84	0.04
Maturity Offset (years to PHV)	**'CONT'**	*34*	-3.20	0.48	*32*	-2.89	0.56	*33*	-2.57	0.55
	'PASS'	*44*	-3.25	0.47	*43*	-2.70	0.46	*41*	-2.38	0.48
	'HIPA'	*36*	-3.21	0.39	*35*	-2.65	0.39	*33*	-2.35	0.41
	'FMS'	*35*	-3.49	0.43	*35*	-3.00	0.43	*37*	-2.72	0.46

nonOW = non overweight, OW = overweight, OB = Obese (Chinn & Rona, 2004)

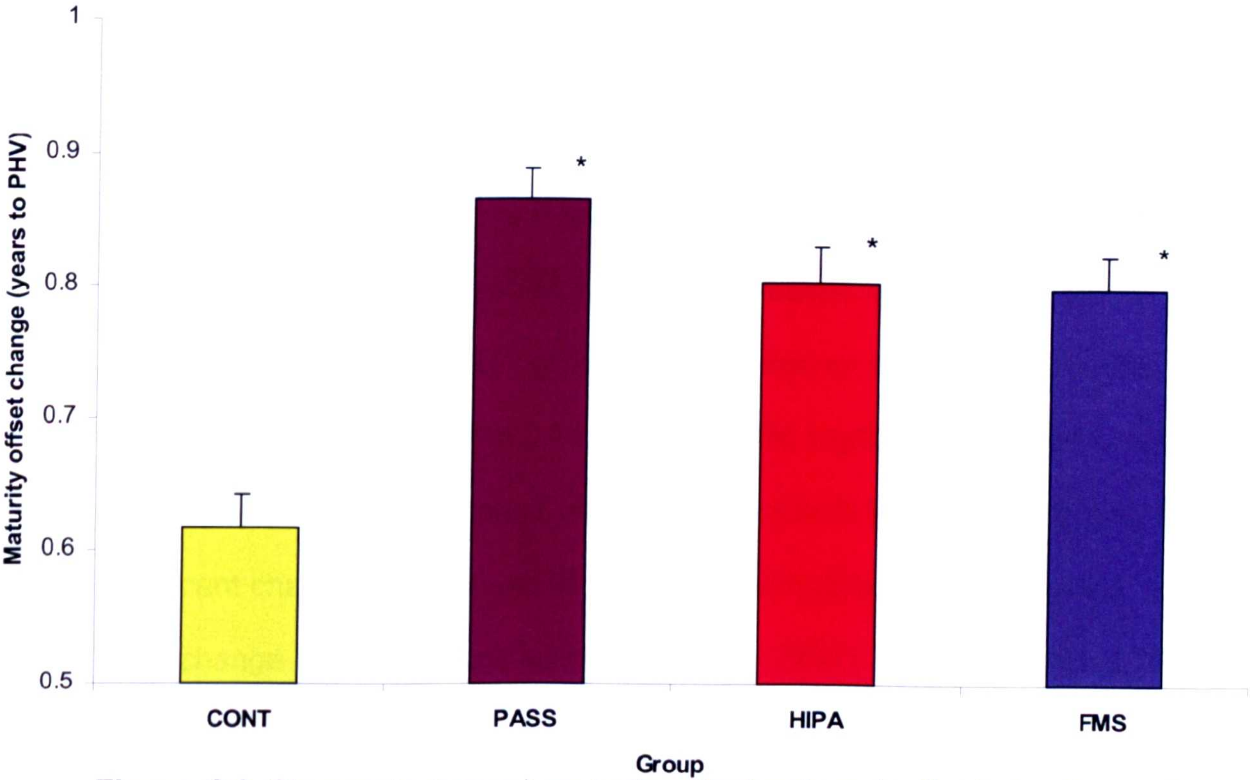


Figure 6.3 Change in (mean) maturity offset values to illustrate change in maturity during 12 month intervention
* *P*<0.001 compared to 'CONT' group.
'PASS', 95% CI: -0.32 to - 0.18; 'HIPA', 95% CI: -0.26 to -0.11; 'FMS', 95% CI: -0.25 to -0.11

Significant changes in maturity offset between 9 and 12 months were observed by the 'PASS' group compared to the 'CONT' group (95% CI: -0.13 to -0.02; *P*=0.01), with no significant maturity offset change by 'HIPA' and 'FMS' groups (Both *P*>0.05) over this time period. Despite the accuracy limitation of using the maturity offset calculations in children outside of 2 years PHV (Mirwald *et al*, 2002), the different maturity offset trajectories between groups highlight the importance of using maturity offset as a covariate.

Waist circumference and waist-hip ratio changes adjusted for maturity offset change and baseline variable account for any morphological maturation changes during the intervention. Waist circumference increased during the intervention across all groups. The 'PASS' group showed a significant increase (change) in waist circumference during 0-9 months compared to the 'CONT' group change (95% CI: -3.50 to -1.08; *P*<0.001). The mean waist circumference increase in the PASS group was 2.3 cm more than the 'CONT' group. The 'FMS' group also significantly increased waist circumference by 1.5 cm more than 'CONT' group change during the first 9 months of intervention (95% CI: 2.73 to 0.24; *P*=0.019). No significant changes in waist circumference between groups were found in the 0-12 month data set, but significant changes were found in the 9-12 month data set by all groups. The most change (increase) was recorded by the 'CONT' group (2.18 cm). The intervention group's waist circumference changes were significantly less than the 'CONT' group; the 'PASS' group showed the most change with 1.45 cm less than the 'CONT' change (95% CI: 0.51 to 2.39; *P*=0.003). The 'HIPA' group change was 1.17 cm less (95% CI: 0.16 to 2.19; *P*=0.02) and the 'FMS' change was 1.08 cm less than 'CONT' group change (95% CI: 0.16 to 2.01; *P*=0.02).

6.3.3 Bone mineral changes

One hundred and thirty-four complete data sets were obtained for total body and lumbar spine scans (girls n=81, boys n=53) and 127 (girls n= 77, boys n=51) for femoral neck scans at baseline, 9- and 12 month test points (Table 6.6). Changes from baseline to mid-intervention (9-months) and baseline to post-intervention (12 months) between groups were analysed using ANCOVA, adjusted for the baseline variable and lean mass change (LMΔ).

6.3.3. i Total body bone mineral

Baseline adjusted change scores revealed that the 'PASS' group showed significant increase in BMC_{TB} from baseline to 9 months (40.1g or 3.67%; 95% CI: -62.23 to -17.99; $P<0.001$) and both 'PASS' and 'FMS' groups showed significant change compared to 'CONT' change from 0-12 months ('PASS': 54.8 g or 4.99%; 95% CI: -83.20 to -26.30; $P<0.01$; 'FMS': 32.4g or 2.95%; 95% CI: -61.5 to -3.17; $P=0.03$). The increase change of 29.2 g or 2.63% observed by the 'HIPA' group over 12 months neared significance ($P=0.058$).

With the addition of LMΔ as a covariate, the 'PASS' intervention displayed the most BMC_{TB} gain over the initial 9 months (mid-intervention), with a significant change of 36.22 g (3.3%) more than the 'CONT' group (95% CI: -58.4 to -14.0; $P=0.002$). Changes from baseline to 9 months in the 'HIPA' (1.3% change) and 'FMS' (1.8% change) groups were not significant ($P=0.22$, $P=0.08$ respectively) compared to the 'CONT' group. Over 12 months, the 'PASS' group increased BMC_{TB} 44.06 g or 4.0% more than the 'CONT' group (95% CI: -70.4 to -17.7; $P=0.001$; Fig. 6.4) but no significant change was found for the 'HIPA' or 'FMS' intervention groups ($P=0.15$, $P=0.07$ respectively). Neither intervention had significant effect on BMC_{TB} during the 3 month period between 9 and 12 months (all $P>0.05$).

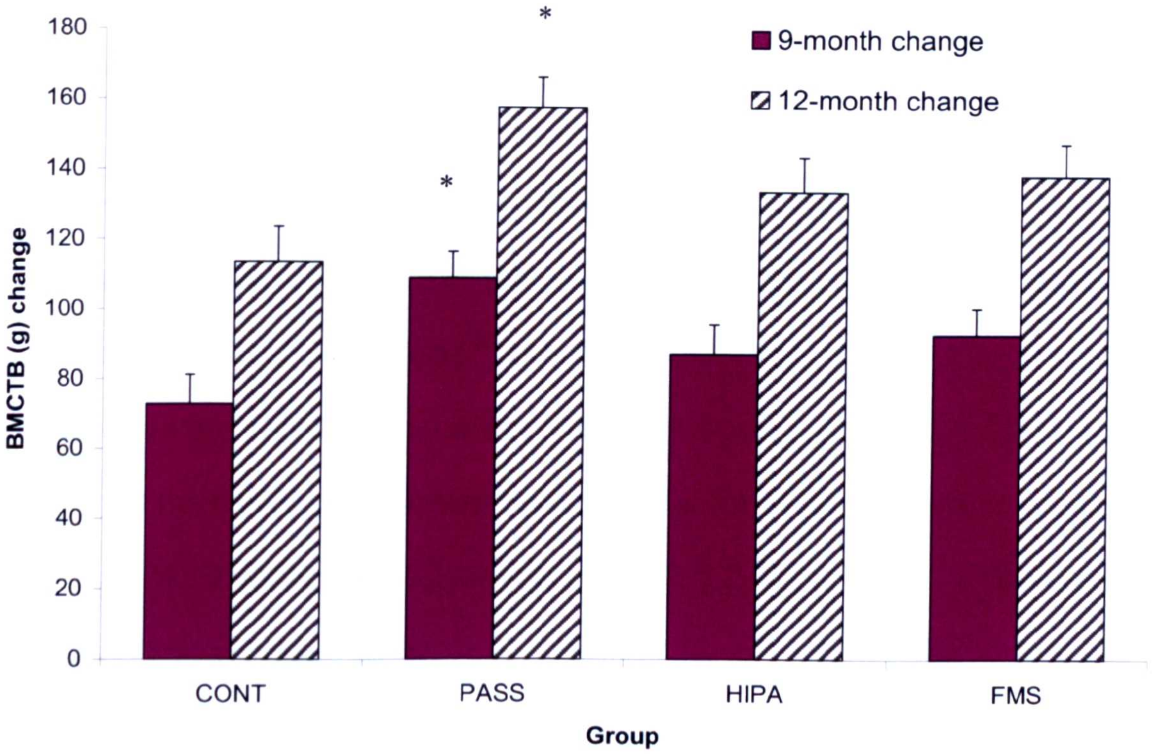


Figure 6.4 Total body BMC adjusted change (increase) over 9 and 12 months of intervention. Adjusted baseline mean was 1095g.
* *P*<0.05 Significant compared to 'CONT' group change

When PA variables; PA_{Total}, PA_4 and PA_8 (Table 6.11) were controlled for (individually) in the analysis, no significant differences between groups were detected for 0-9 months (n=116) or 0-12 months (n=125) intervention. These observations indicated that PA may have influenced BMC change.

For BMD_{TB}, baseline adjusted change scores revealed that when compared to 'CONT', the 'PASS' and 'FMS' intervention improved BMD_{TB} significantly over the initial 9-month period with both showing a mean increase of $0.011g.cm^{-2}$ or 1.3% greater than 'CONT' change ('PASS'; 95% CI: -0.021 to -0.002; *P*=0.02. 'FMS'; 95% CI: -0.021 to -0.001; *P*=0.04). The 'PASS' group also showed a significant change of $0.018g.cm^{-2}$ or 2.2% greater than

‘CONT’ group change (95% CI: -0.03 to -0.01; *P*=0.002) in the 0-12 months data set.

When LMΔ was introduced as a covariate, a significant increase in BMD_{TB} was again observed by the ‘PASS’ and ‘FMS’ groups. Both groups show the same increase of 0.011 $g.cm^{-2}$ or 1.3% (95% CI: -0.02 to -0.001; *P*=0.03) more than the ‘CONT’ group within the first 9 months, thus indicating that LM may not have influenced bone mineral accrual. The mean increase recorded by the ‘PASS’ group over 12 months was 0.015 g.cm-2 or 1.8% greater than ‘CONT’ group change (95% CI: -0.026 to -0.005; *P*=0.005), although this was less than the change recorded when LMΔ was not included in the analysis.

Significant changes in BMD_{TB} between groups were also revealed from the 9-12 month data set. The ‘PASS’ subjects showed a significant increase (change) in BMD_{TB} of 0.006 g greater than the ‘CONT’ group change (95% CI: -0.012 to -0.000; *P*=0.04).

When time spent in PA was controlled, no significant differences between groups were found in 0-9 month (n=116) or 0-12 month (n=125) change data. This finding could indicate that considering previous significant findings, PA was an influencing factor in both ‘FMS’ and ‘PASS’ groups, but not ‘HIPA’.

6.3.3.ii Femoral neck and lumbar spine bone mineral

Compared to the 'CONT' group change, BMC_{FN} significantly increased in all groups when data were adjusted for baseline differences alone. Mean change in BMC_{FN} by the 'PASS' group showed a change (increase) of 1.26 g or 7.4% (95% CI: -2.03 to -0.49; P=0.002) over 9 months, and a total of 1.53g or 8.9% (95% CI: -2.35 to -0.71; P<0.001) more than 'CONT' change. The 'HIPA' group had increased BMC_{FN} by 1.47g or 8.6% by 9 months (95% CI: -2.28 to 0.67; P<0.001), and 1.89 g or 11.1% (95% CI: -2.75 to -1.04; P<0.001) more than 'CONT' after 12 months. The 'FMS' group change was 1.18 g or 6.9% after 9 months (95% CI: -1.99 to -0.38; P=0.004) and 1.71g or 10.1% (95% CI: -2.56 to -0.85; P<0.001) greater than changes observed by 'CONT' group after the 12 month intervention period.

When BMC_{FN} change was adjusted for LM Δ in addition to baseline BMC_{FN}, all groups increased BMC_{FN} significantly more than the 'CONT' group over 9 months, but only the 'HIPA' group increased their BMC_{FN} significantly more than the 'CONT' group over 12 months, Table 6.8 displays the percentage increase above the 'CONT' group. The effect sizes, however, were less than when the change scores were adjusted for baseline variables alone, which highlights the dampening effect of LM Δ as a covariate.

Table 6.6. Raw DXA-bone mineral content (BMC) and bone mineral density (BMD) data from baseline, mid-test (9 months) and post-test (12 months) by intervention group

		Baseline			Mid-test			Post-test		
Bone mineral variables - DXA		***N***	**M**	**sd**	***N***	**M**	**sd**	***N***	**M**	**sd**
BMC_{TB} (g)	**'CONT'**	29	1104.2	140.77	29	1176.7	168.18	29	1214.7	186.66
	'PASS'	39	1089.4	113.87	39	1202.8	141.05	39	1252.9	155.17
	'HIPA'	33	1123.1	111.01	33	1215.6	127.42	33	1267.7	140.33
	'FMS'	33	1065.5	150.52	33	1154.2	167.84	33	1197.1	173.55
BMD_{TB} (g.m-2)	**'CONT'**	29	0.82	0.06	29	0.83	0.07	29	0.84	0.07
	'PASS'	39	0.82	0.04	39	0.84	0.04	39	0.86	0.05
	'HIPA'	33	0.83	0.04	33	0.85	0.05	33	0.86	0.05
	'FMS'	33	0.81	0.07	33	0.83	0.06	33	0.84	0.06
BMC_{FN} (g)	**'CONT'**	27	17.2	3.20	27	18.0	4.02	27	19.1	4.15
	'PASS'	37	16.8	2.69	37	18.9	3.38	37	20.1	2.99
	'HIPA'	33	18.3	2.56	33	20.7	2.59	33	22.0	2.87
	'FMS'	30	15.6	3.34	30	17.6	3.51	30	19.2	3.56
BMD_{FN} (g.m-2)	**'CONT'**	27	0.74	0.07	27	0.75	0.08	27	0.76	0.08
	'PASS'	37	0.74	0.06	37	0.76	0.07	37	0.78	0.07
	'HIPA'	33	0.73	0.06	33	0.77	0.06	33	0.78	0.07
	'FMS'	30	0.71	0.08	30	0.74	0.08	30	0.75	0.08

Over the initial 9 months, a mean BMC_{FN} change (increase) of 0.89 g (95% CI: -1.60 to -0.18; *P*=0.015) was observed by the 'PASS' group, a change of 1.27 g (95% CI: -2.00 to -0.54; *P*=0.001) by the 'HIPA' group, and 0.96 g (95% CI: -1.69 to -0.23; *P*=0.010) by the 'FMS' group. Over 12 months, the 'PASS' group recorded a 1.19g change (95% CI: -1.95 to -0.44; *P*=0.002), a 1.67g change was recorded by the 'HIPA' (95% CI: -2. 46 to -0.89; *P*<0.001) and 1.14g change by the 'FMS' group (95% CI: -2.22 to -0.65; *P*<0.001) over and above the change observed by the 'CONT' group. When adjusted for PA (PA_{Total}, PA_4–Figure 6.5 and PA_8); 'HIPA' and 'FMS' groups showed significant changes (increase) in BMC_{FN} at 9 months (n=111), and significant change was also found by 'HIPA' group at 12 months (n=119) data.

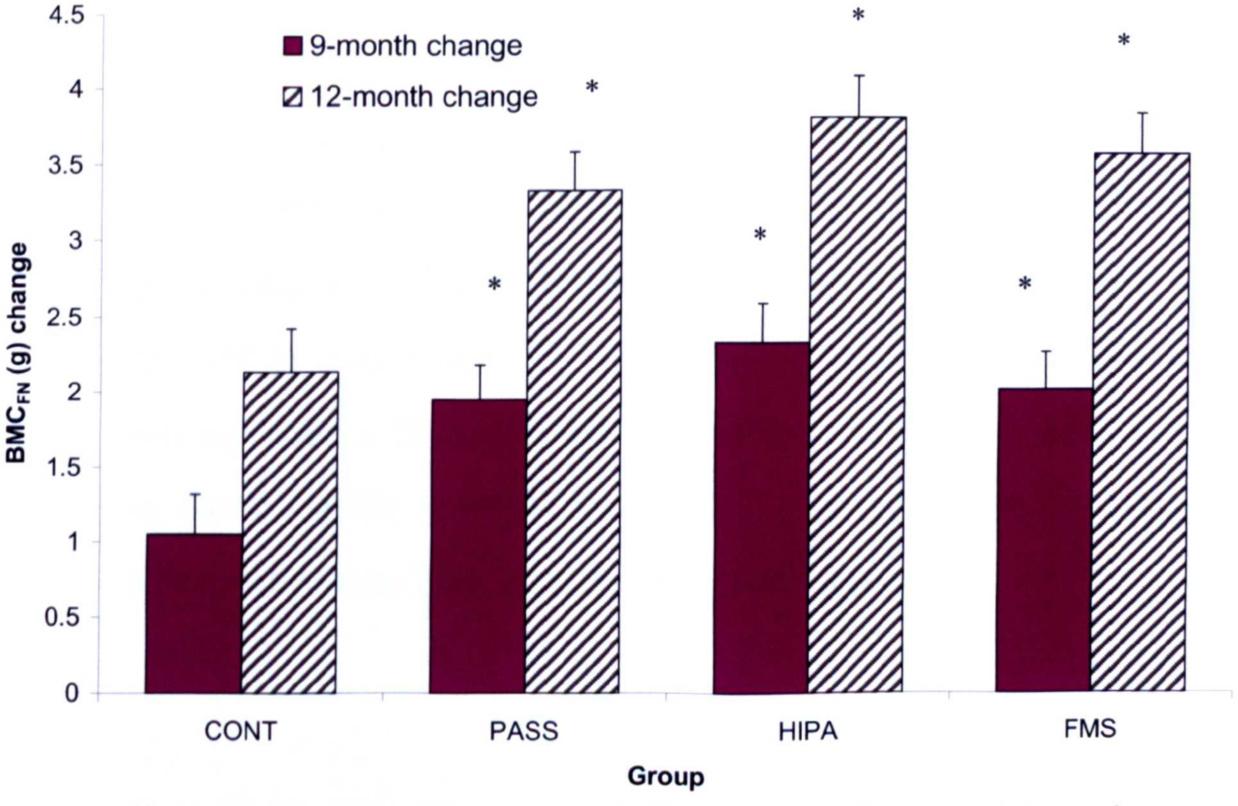


Figure 6.5 Adjusted Femoral neck BMC change (increases) in each group over 9 and 12 months intervention. Adjusted mean baseline value:17.01 g.
*Significant change compared to 'CONT' group (*P*<0.05)

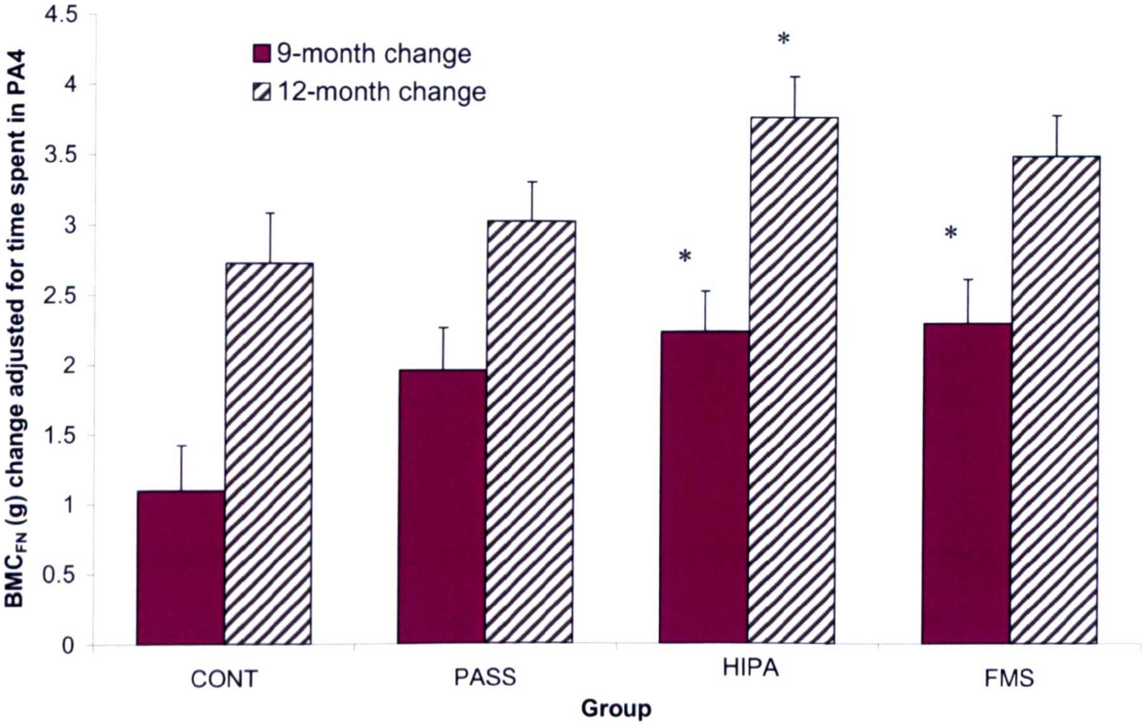


Figure 6.6 Femoral neck BMC adjusted change (increases) in each group over 9 and 12 months intervention when time spent in PA$_4$ was controlled. Adjusted baseline mean value: 16.96g.
* Significant change compared to 'CONT' group ($P<0.05$)

When change scores were adjusted for baseline, BMD$_{FN}$ increased across all intervention groups compared to the 'CONT' group (Fig. 6.6). The 'HIPA' group demonstrated the only significant additional change over 9 (0.033 g.cm^{-2}, 95% CI: -0.05 to -0.017; $P<0.001$) and 12 months (0.037 g.cm-2; 95% CI: -0.05 to -0.02; $P<0.001$). The 'PASS' and 'FMS' group increases were only significant at 12 months, with an increase of 0.02 g.cm^{-2} (95% CI: -0.03 to -0.003; $P=0.02$) by 'PASS' and 0.02 g.cm^{-2} or 2.7% (95% CI: -0.04 to -0.004; $P=0.014$) by 'FMS' more than the 'CONT' group.

Table 6.7 Percentage gain of BMC_{FN} and BMD_{FN} by intervention groups over the gain recorded by the 'CONT' group at 0-9 and 0-12 months

Adjusted measure (baseline and LMΔ)		Percent increase above 'CONT' group (%)					
		'PASS'	***P***	**'HIPA'**	***P***	**'FMS'**	***P***
BMCFN (g)	9-month	5.2	*	7.5	*	5.6	*
	12-month	7.0		9.8	*	8.5	
BMDFN (g.m^{-2})	9-month	1.4		4.0	*	1.5	
	12-month	1.9		4.2	*	2.2	*

* $P<0.05$

Lean mass adjusted BMD_{FN} changes revealed that, compared to the 'CONT' group, a significant intervention effect was observed by the 'HIPA' group over 9 months and the 'HIPA' and 'FMS' groups over 12 months, Table 6.8 displays percentage gain above that of 'CONT' group. The 'HIPA' group showed a change in BMD_{FN} of 0.024 g.cm^{-2} more than the control (95% CI: -0.04 to -0.01; $P<0.001$) after 9 months. After 12 months the 'HIPA' group change was 0.031 g.cm^{-2} (95% CI: -0.05 to -0.02; $P<0.001$) and the 'FMS' change was 0.017 g.cm^{-2} (95% CI: -0.03 to -0.00; $P=0.033$) greater than the change observed by the 'CONT' group. There was no significant change in BMC_{FN} or BMD_{FN} between groups during the 3 -month period between mid-test and post –intervention testing (All $P>0.05$).

When PA (PA_{Total}, PA_4 – shown in Figure 6.6 and PA_8) was controlled for in the ANCOVA, significant changes in BMD_{FN} were recorded by the 'HIPA' group after 9 (n=111) and 12 (n=119) months intervention indicating that the BMD_{FN} increased independent of PA_{Total}, PA_4 and PA_8.

Neither intervention group had a significant effect on BMC_{LS} over 12 months when change scores adjusted for baseline-alone and with LMΔ were compared to controls. Nor did any intervention group have a significant effect on BMC_{LS} compared to 'CONT' over the first 9 months. The 'FMS' group showed the most change in BMC_{LS} relative to the 'CONT' group, with effect size change of over 0.70g (P=0.12) after 9 months and 1.1g after 12 months (P=0.09), with the effect sizes smaller when adjusted for LM Δ (0-9m: 0.54g; 0-12m: 0.76g).

Baseline adjusted BMD_{LS} change scores also showed no significant intervention effect after an ANCOVA analysis, but the 'HIPA' group displayed the greatest change with $0.08 g.cm^{-2}$ after 9 and $0.15 g.cm^{-2}$, after 12 months , but lacked statistical significance (P=0.27, P=0.10). When mean change scores were adjusted for LMΔ, the effect size of the intervention was reduced further, highlighting the influence LM has on BMD.

6.3.2 Body composition

Baseline, 9 month (mid) and12-month (post) intervention data for body composition results are displayed in Table 6.8 by each intervention group. Complete data sets were obtained for DXA derived body composition variables (pre-mid, pre-post n=134) from baseline to mid-intervention (9-months) and post intervention (12 months). The 9-month and 12-month changes from pre-to-mid-to post intervention between groups were analysed by ANCOVA adjusted for baseline differences and maturity offset change to account for any morphological changes due to growth.

6.3.2. i Body fat changes: Fat mass

Over the 12-month intervention period, total fat mass (FM) increased in all groups. When FM change was adjusted for baseline, no significant changes were observed in intervention groups compared to the 'CONT' group (all $P>0.05$). With the addition of maturity offset as a covariate, no significant FM change was observed between the 'CONT' group and intervention groups (all $P>0.05$) from 0-9months data set, despite the greatest mean change observed by 'CONT' group, with the least change by the 'HIPA' group. Over 12 months, maturity offset adjusted change scores showed that the FM change in the 'HIPA' group was significantly less (0.80 kg less) than 'CONT' change (95% CI: 0.06 to 1.54; $P=0.03$), the 'FMS' change was 0.79 kg less than 'CONT' (95% CI: 0.07 to 1.52; $P=0.03$) and the 'PASS' group change was 0.78 kg less than 'CONT' (95% CI: 0.02 to 1.55; $P=0.04$, Figure 6.7).

Table 6.8. Raw DXA-body composition data from baseline, during (9 months) and post-intervention (12 months) by intervention group

		Baseline			9-months			12-month		
Body composition - DXA		*N*	M	sd	*N*	M	sd	*N*	M	sd
Total Fat mass (kg)	**'CONT'**	*29*	10.0	4.17	*29*	10.4	4.23	*29*	11.4	4.88
	'PASS'	*39*	12.3	4.92	*39*	13.2	5.38	*39*	14.2	5.74
	'HIPA'	*33*	12.0	5.14	*33*	12.7	5.54	*33*	13.7	5.82
	'FMS'	*33*	8.4	4.14	*33*	9.0	4.55	*33*	9.6	4.77
Total Percent body fat (%)	**'CONT'**	*29*	27.3	5.04	*29*	26.7	5.05	*29*	28.0	5.47
	'PASS'	*39*	30.4	5.34	*39*	29.9	5.77	*39*	30.4	5.58
	'HIPA'	*33*	28.9	7.31	*33*	28.4	7.75	*33*	28.9	8.09
	'FMS'	*33*	24.3	7.05	*33*	24.0	7.10	*33*	24.3	6.98
Trunk fat mass (kg)	**'CONT'**	*29*	3.4	1.91	*29*	3.9	2.37	*29*	4.0	2.34
	'PASS'	*39*	4.6	2.39	*39*	4.9	2.51	*39*	5.3	2.76
	'HIPA'	*33*	4.5	2.54	*33*	4.8	2.76	*33*	5.5	3.62
	'FMS'	*33*	2.9	1.90	*33*	3.1	2.06	*33*	3.4	2.21
Percent trunk fat (%)	**'CONT'**	*29*	21.1	6.00	*29*	20.8	6.07	*29*	27.6	5.47
	'PASS'	*39*	25.2	6.71	*39*	25.0	6.86	*39*	30.4	5.58
	'HIPA'	*33*	24.1	8.04	*33*	24.0	8.77	*33*	28.9	8.09
	'FMS'	*33*	19.0	7.54	*33*	18.7	7.49	*33*	24.3	6.98

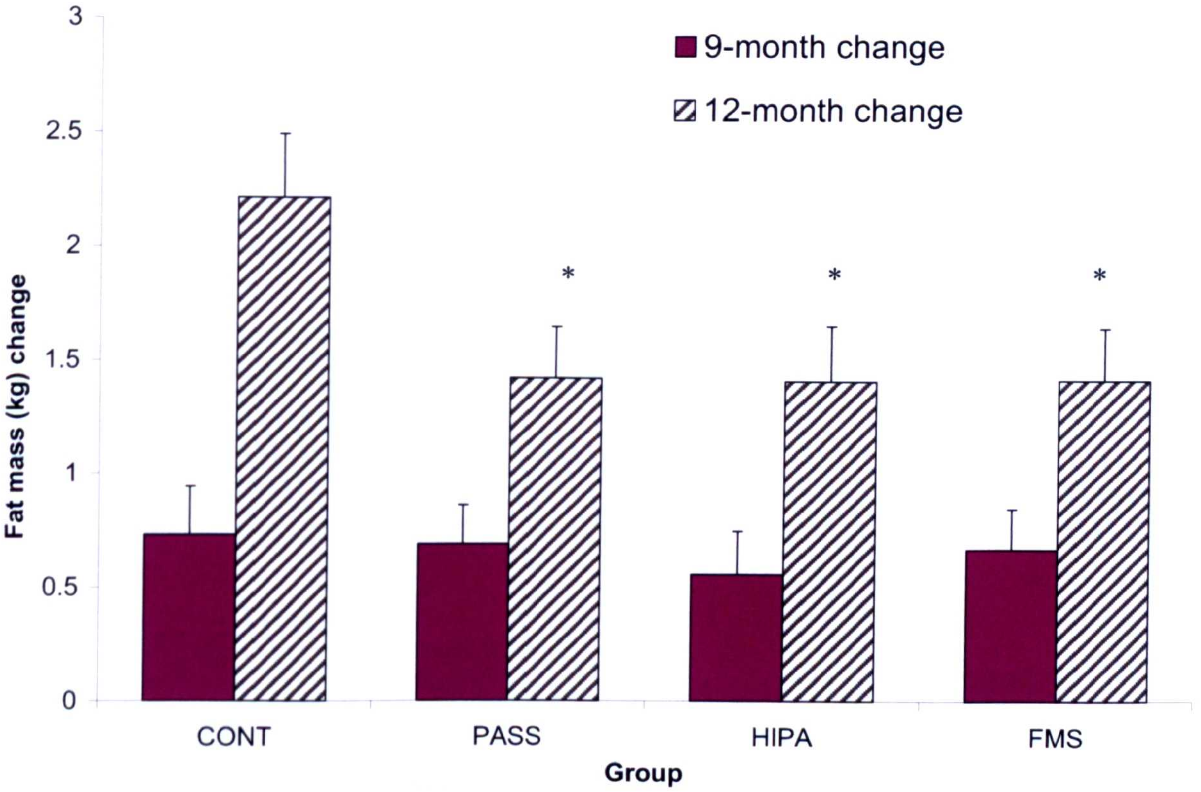


Figure 6.7. Mean fat mass (kg) change data at 9 and 12 months.. Mean adjusted baseline fat mass was 10.78kg.
* *P*<0.001 Compared to 'CONT' group

When total FM change was adjusted for change in time spent in PA_{Total}, PA_4 and PA_8, no significant changes were detected between groups over 9 month intervention (n=116). Over 12 months intervention (n=125), when time spent in PA_{Total} was adjusted for, the increase (change) in fat mass observed by all intervention groups was smaller than the change observed by 'CONT' group (*P*>0.05). The same was true for the change effect when time spent in PA_4 (Figure 6.8) and PA_8 were adjusted for, but the magnitude of change was greatest between the 'CONT' and 'HIPA' group, the 'HIPA' group showed the least increase in fat mass over 12 months intervention (PA_4 *P*=0.059; PA_8 *P*=0.065). Despite no sex by group interactions, the change (increase) in FM in the boys was greater than in the girls in all groups apart from the 'HIPA' group where girls increased fat mass more than boys over the 12 months of intervention.

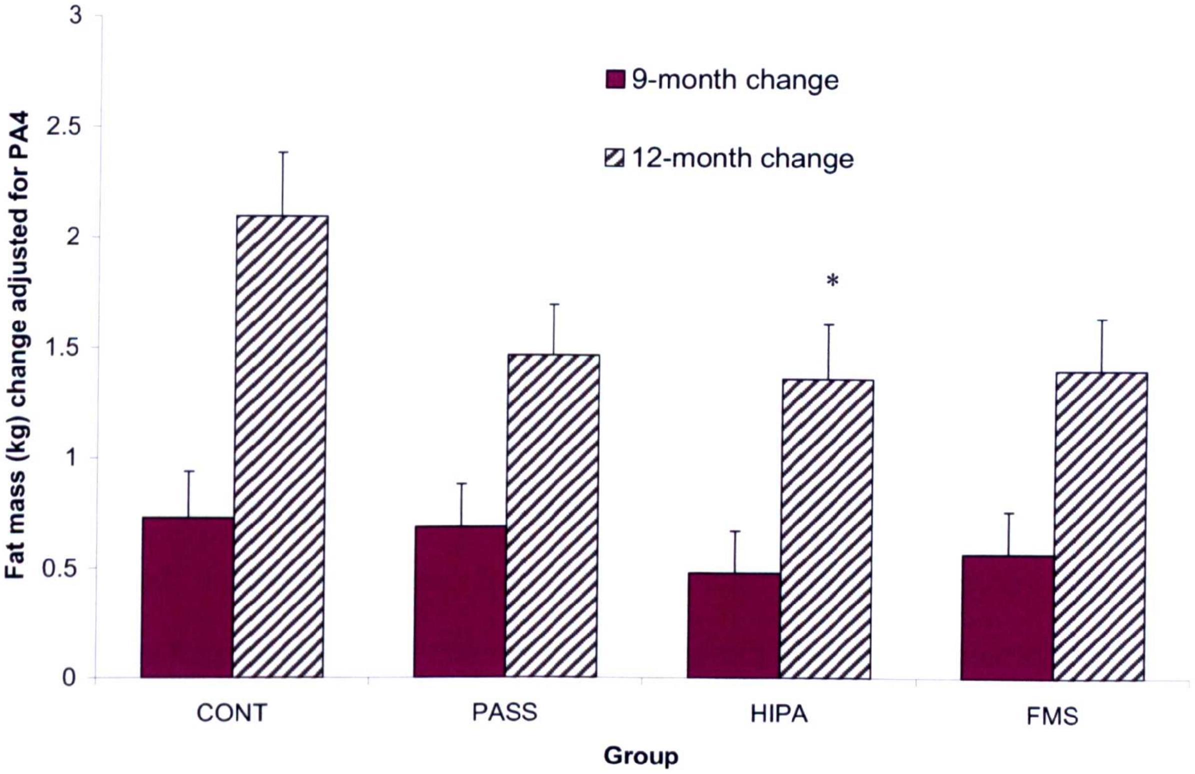


Figure 6.8 Fat mass (kg) change over 9 and 12 months of intervention independent of time spent in physical activity (PA_4). Adjusted baseline mean was 10.99kg.
* *P*<0.05 compared to 'CONT' group

The change in trunk fat mass also increased in all groups over time, when adjusted for baseline alone, the 'FMS' group displayed the most increase in trunk fat and the 'PASS' group the least (*P*>0.05) over the 12 month intervention period. No significant changes were revealed when maturity offset change was included as a covariate, the trend showed the 'CONT' group displayed the most increase in trunk fat mass between 0-9 months and 0-12 months, and the 'HIPA' displayed the most increase between 9-12 months, whereas the 'FMS' group showed the least increase during 0-9 months and 9-12 months and the 'PASS' group showed the least increase overall during 12 month intervention (0-12months).

6.3.2. ii Percent Body Fat

The ANCOVA adjusted change scores revealed that when compared to the 'CONT' group no intervention had a significant effect on percent body fat after 9 or 12 months. After adjusting for maturity offset change, the greatest change (0.5% decrease) in %BF was observed by the 'HIPA' group at 9 months with change of 0.2% less than 'CONT' (P>0.05). The largest change after 12 months was recorded by the 'FMS' group, where percent body fat increased 0.95% less than the 'CONT' group change (P=0.13). After adjusting for maturity offset change the 'FMS' group decreased their trunk fat percent the most and 'PASS' the least at 9 months. After 12 months, the 'CONT' group and 'FMS' group, increased and decreased percent trunk fat the most and least respectively ('FMS' 1.8% less than 'CONT') (95% CI: 0.16 to 3.74; P=0.03, Figure 6.9).

When physical activity was introduced as a covariate ($PA_{Total,\ 4\ or\ 8}$), no significant changes where detected in percent body fat over 9 or 12 month. At 9 months, percent body fat decreased in all groups, with 'HIPA' displaying the greatest and 'CONT' group the smallest change. After 12 months only the 'HIPA' group and the 'FMS' group decreased percent body fat, the 'PASS' and 'CONT' group both increased percent body fat, but changes were not significant (P>0.05).

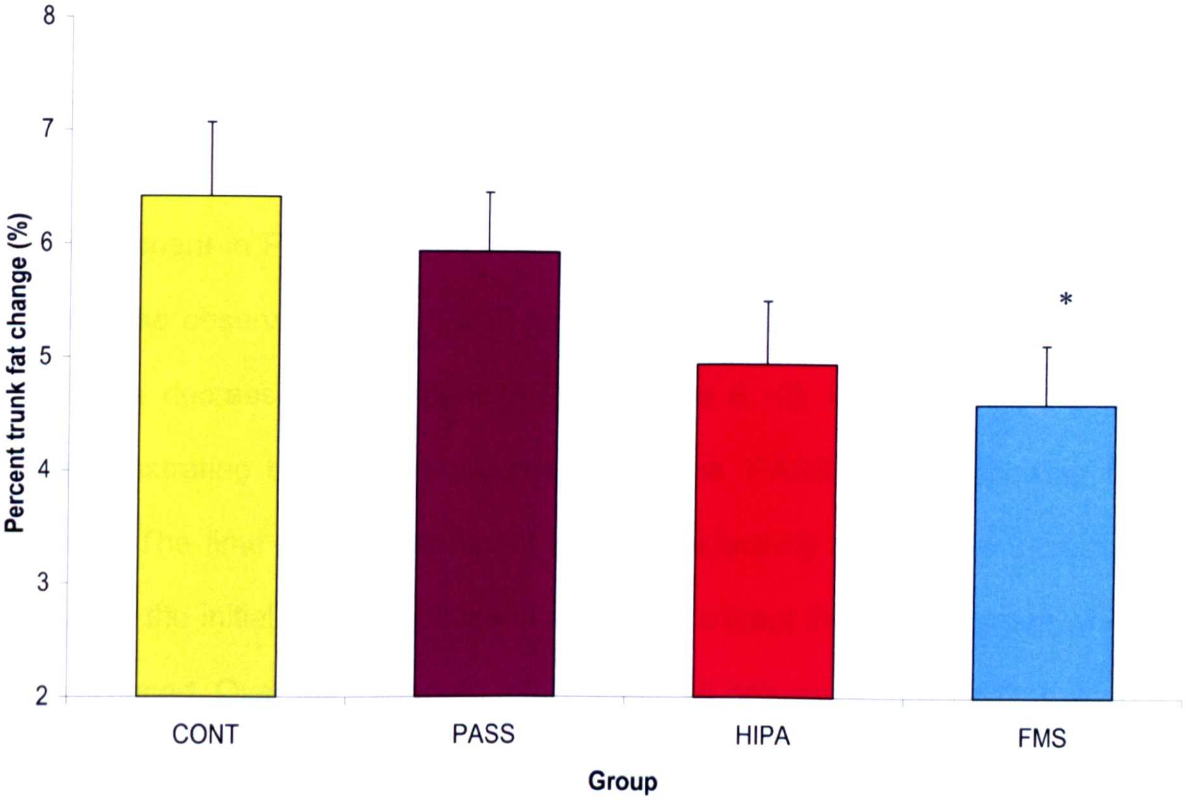


Figure 6.9 Percent trunk fat change over 12 month intervention.
* *P*<0.05 compared to 'CONT' group change

6.3.5 Physical Activity

The time spent in PA at each time-point of the intervention for each group is shown in Table 6.9. Change scores were adjusted for baseline values only. No significant change in time spent at PA_{Total}, PA_4 or PA_8 was recorded after 9 or 12 months of intervention. Regarding PA_{Total}, Tall he HIPA, FMS and PASS groups increased mean time spent in PA_{Total} during 0-9 months of intervention , the CONT group did not increase mean time spent in PA_{Total}. groups except the 'CONT' group increased time spent in PA from 0-9 months of intervention, over 12 months. However, over the 12 month intervention, the results show that all groups displayed a decrease in time spent in PA_{Total}, recording values lower than at baseline. The 'HIPA' group demonstrated the least decrease (19 min), the most decrease in time spent in PA was observed by the 'CONT' group with a 36-min reduction of total PA from baseline.

Time spent in PA_4 increased in all groups over 9 months, with the greatest increase observed by the 'FMS' group. Over the 12 months intervention, all groups decreased time spent in PA_4 (Figure 6.10), with the 'HIPA' group demonstrating the smallest decrease and the 'PASS' groups showing the most. The time the children spent in vigorous activity or PA_8 also increased during the initial 9-month phase in all groups except the 'PASS' group which decreased. Over the 12-month intervention, all groups decreased time spent at PA_8, the 'PASS' group the most (by 35%) and 'FMS' the least (11%).

Table 6.9 Raw physical activity data (min) from baseline, mid (9 months) and post (12 months) test time points

Physical Activity ($min.day^{-1}$)		**Baseline**			**Mid-test**			**Post-test**		
		N	**M**	**sd**	***N***	**M**	**sd**	***N***	**M**	**sd**
Total Physical Activity (PA_{Total})	**'CONT'**	*32*	234.5	39.60	*30*	236.1	58.47	*31*	202.8	43.90
	'PASS'	*44*	244.7	35.03	*33*	245.7	57.02	*40*	216.5	40.59
	'HIPA'	*35*	250.8	38.61	*32*	248.0	43.95	*30*	226.4	60.58
	'FMS'	*33*	227.5	43.39	*28*	237.5	49.04	*35*	199.6	45.75
Physical Activity >4km (PA_4)	**'CONT'**	*32*	73.7	29.60	*30*	86.3	38.08	*31*	65.1	28.53
	'PASS'	*44*	82.8	29.42	*33*	87.1	34.91	*40*	69.3	28.26
	'HIPA'	*35*	87.4	28.02	*32*	87.8	31.05	*30*	66.0	20.10
	'FMS'	*33*	80.8	24.21	*28*	92.2	28.72	*35*	67.6	24.70
Physical Activity >8km (PA_8)	**'CONT'**	*32*	7.0	7.06	*30*	10.1	8.13	*31*	6.1	4.58
	'PASS'	*44*	8.2	6.64	*33*	8.1	7.33	*40*	5.6	4.59
	'HIPA'	*35*	7.7	5.08	*32*	7.7	5.85	*30*	6.0	3.47
	'FMS'	*33*	8.2	9.15	*28*	10.8	10.86	*35*	7.3	7.98

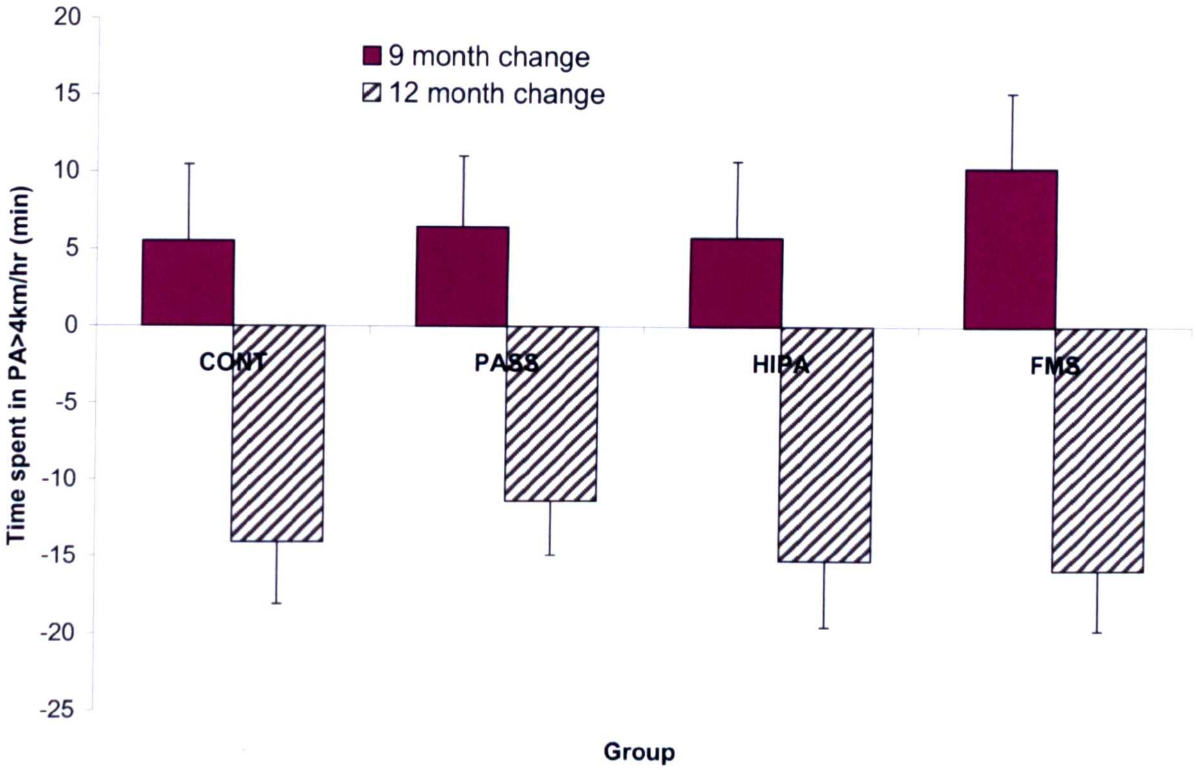


Figure 6.10 The mean change of time spent in PA_4 for each group during the 12 months intervention. Adjusted baseline mean for time spent in PA_4 was 81min.

6.3.6 Main results summary

6.3.6.i Bone Mineral

Total body bone mineral content and density increased the most in the 'PASS' group ($P<0.05$), whereas regional changes at the femoral neck reported by the 'HIPA' and 'FMS' groups showed the greatest significant change. Such changes remained significant when PA was controlled for indicating that these structured intervention programmes (HIPA and FMS) were effective at increasing BMC and BMD at the femoral neck independent of time spent in moderate PA.

6.3.6.ii Body composition

Fat mass increased the most in the 'CONT' group over the 12 month intervention. Changes in fat mass observed by the 'PASS', 'HIPA' and 'FMS' groups were significantly less than the 'CONT' group, but no reduction in fat mass was observed. Percent body fat increased the least in the group receiving the 'HIPA' intervention.

6.3.6.iii Physical Activity

Time spent in physical activity, either total (PA_{Total}), moderate (PA_4) or vigorous (PA_8) decreased over the intervention period. The 'PASS', 'HIPA' and 'FMS' groups increased total physical activity during the 0-9 month phase, whereas the 'CONT' groups remained the same. Over 12 months the decrease in PA was observed by all groups, with the least decrease apparent in the 'HIPA' group.

6.4 Discussion

The aim of this 12-month intervention was to study the effects of 3 different PA interventions on body composition, bone, physical activity and fitness in 9-11 year old children. The aim was to have a positive impact on body composition. Analysis of covariance was used to compare the effects of the different interventions at baseline, 9 months and 12 months. After adjusting for maturity and physical activity, significant changes were evident in both body fat and bone mineral properties but these varied according to intervention group.

6.4.2 Intervention effect on bone mineral

The significant change in total body BMC by the 'PASS' group (193 g) over the 12-month intervention period was 4% (3.3% 0-9 months) greater than the change experienced by the 'CONT' group. The magnitude of change in

BMC_{TB} observed by the 'HIPA' (133 g) and the 'FMS' (128 g) group was not significant. On the other hand this study yielded more favourable changes than a shorter duration but more intense intervention (Barbeau et al., 1999), but less favourable than a longer structured and lifestyle intervention (Gutin et al., 1999). Habitual PA levels may also have influenced BMC change, but no significant change in BMC was detected when PA was introduced into the analysis. This observation suggests that PA was an influencing factor in the changes observed in total body BMC over 12 months.

The 'PASS' and 'FMS' groups both significantly increased BMD_{TB} by 1.3% (0.01 $g.cm^{-2}$) more than the 'CONT' group over 12 months when lean mass was controlled for. This was similar to the 0.02 $g.cm^{-2}$ change observed by Barbeau *et al.* (1999) in the study previously discussed. No significant changes were found when HPA was accounted for in the analysis, which suggests that HPA had an effect on the outcome. Again, it is unclear why the 'HIPA' intervention did not show any significant effect, particularly as the 'HIPA' treatment is similar to the physical training programme of Barbeau *et al.* (1999), and is supported by the mechanostat theory underpinning mechanical loading and bone mineral accrual. In addition to this, the 'PASS' intervention was not structured and the 'FMS' intervention, though structured was skill based with less emphasis on vigorous weight-bearing activity shown to have more effect on bone mineral density. The 'PASS' cohort did, however, experience the most advancement in maturation over the 12-month intervention period, which could be a reason why bone mineral density increased the most. However, it is unlikely that they had entered puberty, given the maturity offset score. Maturity offset was accounted for in ANCOVA analysis, and therefore, it is unlikely that maturity status had any effect. Dietary differences or changes specifically in calcium intake could also have had an effect on bone mineral accrual, but nutrient intake was not measured in this study. Missing vigorous physical activity data from other days in the week may have also accounted for this unexpected outcome, as full 7 day HPA was not accounted for, only 3 days out of 7 days physical activity was accounted for in the analysis.

Significant changes were apparent from the 'HIPA' intervention in regional BMC and BMD changes. The magnitude of change in femoral neck BMC and BMD achieved by the 'HIPA' (BMC: 1.89 g; 11.1%) group in this study was 9.8 % more than the 'CONT' group and greater than change observed by McKay *et al.* (2005) (0.19 g), greater than the 1.18g change observed during the 9-week exploratory trial (Chapter 4, Study 1) and similar to percentage change (9.3%) reported by Hienonen *et al.* (2000) in premenarcheal girls. The intervention by McKay *et al.* (2005) involved an isolated jump activity where children performed 10 counter-movement jumps 3 times per day (school day) for 8 months, whereas the 'HIPA' intervention in this present study provided a general physical activity of high-intensity games and activities, which would suggest that the dose of bone loading was likely to be greater than that experienced in the McKay *et al* (2005) study. The magnitude of change observed for the 'HIPA' group was also greater than the 1.6% increase reported by MacKelvie *et al.* (2003) after a 20-month jump-based programme with girls of a similar age. Given that the 'HIPA' programme was not specifically jump based, and it included a mixed sample, these encouraging results support the notion that high-intensity weight-bearing games activities may be more effective than jump-based programmes on bone health. This study's findings support current research, that high-intensity physical activity is most effective at increasing BMC and BMD at the femoral neck. This positive change in regional bone development may be due to the nature of the activity given that children participated in game-like activities involving running, jumping, skipping and strength and conditioning exercises, with an emphasis on mass participation and inclusion. The associated benefits of physical activity of a vigorous, loading nature on bone mineral is widely supported in literature (Fuchs *et al.*, 2001; MacKelvie *et al.*, 2001; Ginty *et al.*, 2005; Linden *et al.*, 2006; Hasselstrom *et al*, 2007; Tobias *et al.*, 2007) and further supported by Sardinha *et al.* (2008). From investigation of a large cohort of 297 9-year-old Portuguese children, Sardinha et al. (2008) suggested that approximately 25 min per day of vigorous activity is sufficient to promote significant increases femoral neck bone strength and BMC. Sardinha et al. (2008) measured physical activity by accelerometry over 4 days, but physical activity was analysed using a 1-minute epoch setting, which can lack sensitivity when measuring vigorous activity and should therefore be viewed with caution. Although, intensity of activity lessons was not recorded by accelerometry in this study, heart rate analysis confirmed the vigorous nature of the sessions, where the children in the 'HIPA' group participated in a mean of 14 minutes at 75% of maximal heart rate. The volume and type of physical activity performed outside of sessions could not be controlled, only monitored. Habitual physical activity was only recorded at each test phase and PA data were included in the analysis to control to any changes in PA but the fact that significant femoral neck bone mineral changes were independent of PA indicates that the intervention was an effective stimulus for bone mineral accrual.

Femoral neck changes between baseline and 9 months showed a marked and significant difference between treatment groups and the 'CONT' group. This difference continues between 9-12 month data sets, but the slope of the line was less steep; this finding could be due to the summer break and or the length of the latter intervention period (3 months) compared to the 9-month period prior to the summer break. The outcomes suggest that the treatment groups experienced greater bone mineral accrual than the 'CONT' group over 0-9 month time period.

The results indicate that 'HIPA', 'FMS' and 'PASS' programmes stimulate the development of bone mineral accrual at the femoral neck region over and above any maturational changes. The most beneficial treatment was the 'HIPA' programme, in which children were exposed to high-intensity weight-bearing physical activity. Data from the 3 year study of Gutin *et al.* (2008) showed that children of a similar age respond to weight-bearing activities, similar to those in this study. Gutin and colleagues' (2008) work also highlights the loss of intervention effect during school calendar breaks, which was reflected in the gradient of the slope showing the 9-12 month change.

Linden *et al.* (2006) used a non-jump based intervention and found no significant change in femoral neck BMC or BMD but did record a significant positive change in total body bone mineral, which was not evident in this study or in the jump-based intervention of MacKelvie *et al.* (2003). The disparity in results between this study and the work by Linden *et al.* (2006) could mean that 200 min. week^{-1} or 40 min. day^{-1} of activity such as semi-structured running, jumping and skipping is insufficient to promote positive changes in BMC_{FN} but was adequate to promote total body BMC. In contrast, this study's 2 x 60 min.week^{-1} programme of similar activity was sufficient to promote bone mineral gains at the femoral neck, but not in total body. Weeks *et al.* (2008) also found significant gained in total body BMC (boys) following PE lessons twice weekly by incorporating 10 min of jumping exercises in to the warm up, similar significant changes were also evident in the exploratory trial of this study (Chapter 4, Study 1) in a mixed sample. It is somewhat disappointing that total body bone mineral changes were not evident in this study and that the significant changes observed in the shorter (9 week) exploratory trial were not reproduced.

With regard to total body bone mineral (BMC_{TB}, BMD_{TB}) accrual, the null hypothesis that physical activity in the form of 'HIPA', 'FMS' or 'PASS' does not have a significant effect in enhancing BMC or BMD is accepted. It is noteworth however that all intervention programmes had some positive effect on bone mineral accrual (though not significant) compared to the 'CONT' group. With regard to regional bone mineral (femoral neck) accrual, the null hypothesis is rejected as the group participating in high- intensity physical activity ('HIPA') accrued significant levels of BMC and BMD over the intervention period, superior to that of the 'CONT' and other treatment groups. The results from the study support the association between games like activity and bone health only with regard to femoral neck bone mineral accrual. In this region, the findings support the common consensus that vigorous physical activity is likely to be more osteogenic than light physical activity. The evidence from the research discussed in chapter 2, supports the mechanostat theory of mechanical loading as a consequence of physical activity is likely to account for changes at the femoral neck, as it is a key loading site. The significant gains observed by all intervention groups highlights this view, but the greatest change was observed with the 'HIPA' intervention, which is likely to have given the greatest mechanical stimulus (though not measured) in terms of loading. The findings suggest that the changes could be due to dose-response, particularly as such changes were also observed independent of HPA. These findings support previous research by suggesting that loading in the form of moderate-vigorous physical activity may be more effective at encouraging bone mineral accrual than isolated movements. Such activities may be perceived as more attractive to children and therefore have more ecological validity than repetitive jump based programmes. Limited association and supporting evidence however is available for total body bone mineral. It remains unclear to what extent and what type of physical activity influences total bone mineral accrual.

The bone mineral outcomes suggest that programmes that encourage physical activity without dietary restriction or intervention can improve bone mineral accrual in children. Programmes that offer structured high-intensity weight-bearing activities are likely to be more advantageous to regional stimulation of bone mineral. As beneficial effects may be lost during periods of non-activity (school holidays) or post intervention, efforts must be made to sustain levels of interest in physical activity to promote prolonged engagement in a physically active lifestyle in order to reap benefits in bone health and body composition.

6.4.1 Intervention effect on body fat

This study rejects the null hypothesis that high-intensity physical activity does not have a significant effect on the body composition in children as the 'HIPA' group demonstrated slower fat gain than other groups. All treatment groups showed smaller increases in body fat mass than the 'CONT' group. After 12 months the 'HIPA' group gained 7% (relative) less body fat than the 'CONT' group even after time spent in total physical activity was accounted for. On the basis that the 'HIPA' group gained fat at a slower rate than the other group, the 'HIPA' intervention had a positive effect on body fat mass. This finding supports the consensus that vigorous activity is associated with lower levels of body fat (Abbot and Davies, 2004; Ekelund *et al.*, 2004; Denker *et al.*, 2006; Ruiz *et al.*, 2006). The 'FMS' group also gained percent body fat at a slower rate compared to 'PASS' and 'CONT' groups. Therefore, both 'HIPA' and 'FMS' interventions had an effect on body fat; by minimising its increase, with the 'HIPA' intervention having the greatest effect. These findings differed from other reports in the extant literature. The intensity or volume of the 'HIPA' and 'FMS' sessions minimised the increase in body fat. Structured sessions ensured the intensity of the activity was sustained, with mean intensity of 'HIPA' and 'FMS' sessions recorded at 73% and 69% of HR_R respectively. The heart rate data for the 'HIPA' sessions satisfied the criterion (70%) utilised by Gutin *et al.* (1999, 2002, 2008) who reported reductions in percent body fat obese children. The 'FMS' heart rate data were marginally short of this criterion, but the 'FMS' group still demonstrated the smallest ($P<0.05$) increase in absolute trunk fat (0-9 months) and percent trunk fat between 9 and 12 months, with a percent trunk fat increase of 4.6%, compared to the 'CONT' group which increased percent trunk fat by 6.4% (Fig. 6.6).. The results from this study show that the 'FMS' intervention had a positive impact on fat patterning, specifically around the abdominal region. This observation potentially suggests that the structured nature, type and the intensity of the activity effective at mobilising fat from central region. However, no significant abdominal changes were observed for the 'HIPA' group, which does not support the association between vigorous activity and risk associated with high abdominal fat (Ortega *et al.*, 2007). Findings suggest that the type of activity (skill based) may have had more effect on abdominal regions. It is however more likely that as the 'HIPA group had 50% more trunk fat mass before the intervention, the increase in fat mass involved in natural growth and development may be expected to be greater in the 'HIPA' group as opposed to the FMS group, independent to the intervention. The results are also encouraging in that each groups waist circumference and DXA-derived trunk fat data (Appendix C:4) at each time point was less that the respective cut-off point for high trunk fat for growing children (Taylor *et al.*, 2000).

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The magnitude of change in % body fat achieved by the intervention groups was less than the changes observed by Gutin *et al.* (2002) in 13-16 year old adolescents. Gutin *et al.* (2002) reported a significant reduction of 3.6% body fat when the exercise programme (2 times a week) was combined with an education programme. No significant reductions in % body fat were found in this study. Diet could also possibly be a key factor to this outcome; diet could contribute more to body fat than physical activity, as baseline results found that even those children that met PA guidelines were still overfat. The results are encouraging in that they indicated that the rate of increase of % body fat over 12 months was slower in the 'HIPA' and 'FMS' groups compared to the 'CONT' and 'PASS' groups which increased % body fat by 0.6% and 0.1% respectively. The changes in % body fat observed by the 'PASS' group supports the previous suggestion that structured exercise ('HIPA' and 'FMS') may be more effective at slowing the increase of body compared to unstructured exercise ('PASS'). It is noteworthy that the significant reductions reported by Gutin *et al.* (2002) were a result of combining exercise and education groups (exercise alone did not produce any significant change in percent body fat). In this study groups were not combined, and each intervention effect was assessed separately. In Gutin *and colleagues'*(2008) more recent 3-year study, a reduction of 0.5% body fat was reported in its first year, approximately 0.2% in its second, and approximately 1.5% in its third year. Over the 3 years, the overall increase of 1% body fat was recorded. Gutin *et al.* (2008) demonstrated that increases in % body fat occurred during each summer break. The reductions recorded each year may have been a result of a higher volume of physical activity (80 min 4 x week) compared to this study as the intensity of sessions was similar. The overall increase in % body fat reported by Gutin *et al.* (2008) is somewhat comparable to the trend in this study despite having different study designs, as in both study's the intervention groups rate of increase appeared slower than the controls. The recent report of Martınez Vizcaıno *et al.* (2008) indicated a reduction of percent body fat (0.5%) in 9-10 year old girls over a similar time period (24 weeks) using a similar type of after-school activity programme. The frequency of activity sessions per week (3) was higher and longer in duration (90 min) than in this study, whichsuggests that the programme of Martınez Vizcaıno *et al.* (2008) provided a sufficient dose to reduce body fat, rather than minimise its increase. Martinez Vizcaino *et al.* (2008) also reported that one third of each session was at vigorous intensity (>1700 cpm). Given the plateau effect associated with high-intensity accelerometer readings, the accuracy of accelerometer data in the intervention by Martınez Vizcaıno *et al.* (2008) could be questioned when quantifying dose. It is more plausible that the higher frequency of sessions and longer session duration are likely to be key factors in why % body fat reduced in the 24-week programme, and why only minimal increases were found in this 12-month programme. Unlike Gutin *et al.* (2002, 2008) and the present study, Martınez Vizcaıno *et al.* (2008) assessed body fat with bio-electrical impedance and triceps skin-fold; given that quality of data from DXA assessment is far superior, it is difficult to draw clear comparisons. The lack of interventions which deliver physical activity/exercise training programmes and assess body composition objectively by means of DXA to non-obese children is scant and therefore makes it difficult to compare similar changes observed by other research groups.

Compared to the 'CONT' group, the changes observed by the intervention groups in absolute body fat (fat mass) in this study were also encouraging as they demonstrated that the rate in which fat mass accumulated was again significantly slowed by high intensity exercise. Body fat reference curves (McCarthy et al., 2006) show that childrens' body fat increases at a greater rate between the ages of 9-12 years. It is therefore noteworthy that the high intensity exercise interventions group appears to have slowed this increase. The 'HIPA' group demonstrated a 12.3% increase in fat mass which was significantly less than the 19% increase observed by the 'CONT' group over the 12-month intervention (Fig 6.4). These encouraging results were also observed despite a 6 week break after the 9-month period, where there was only a 2% difference in body fat increase between 'HIPA' and 'CONT'. The increase by the 'HIPA' group thereafter was only two-thirds of the increase observed by the 'CONT' group, suggesting the latter phase of the intervention may have been where the 'HIPA' intervention may have been more effective at minimising body fat increases. Gutin *et al.* (2008) suggested a negative effect of detraining on body fat with a similar summer break design, where any beneficial effect was lost. The fact that significant changes were observed regardless of this 6-week break could imply that the children remained physically active during the summer break and performed similar levels of activity and therefore maintained intervention effect; but this is not supported by PA data nor was PA recorded comprehensively during this 6-week period. On the other hand, the summer break may be a reason why only a minimal effect was observed and no reduction in body fat was recorded, changes in dietary behaviour may have also affected this outcome.

It appears that the rate of increase in body fat was slower in the intervention groups compared to the 'CONT' group and without any emphasis or restriction on food intake and or lifestyle. Previous studies that have restricted diet (Knopfli *et al.*, 2008) and provided lifestyle education (Gutin *et al.*,, 2002., Knopfli *et al.*, 2008) have reported significant decreases in body fat of close to 5% body fat (3.5%, Gutin *et al.*, 2008) and 8 kg fat mass (Knopfli *et al.*, 2008), suggesting that multi-disciplinary approach may be the most effective at reducing body fat. Knopfli *et al.* (2008) used a short term (8-week) programme and reported significant decreases in both % body fat (4.7%) and absolute body fat (8.0 kg) through a higher dose of activity training (2 x 60 min.day^{-1}), diet restriction and education. Such outcomes from a multi-disciplinary programme must be commended but, given the specific population (severely obese 12-25 years) and the restriction in calorie intake the findings are not generalisable, also the individual effectiveness of each disciplinary element (exercise, diet, education) was not assessed, and therefore clear conclusions cannot be drawn regarding PA dose and its true effect on body fat reduction.

To summarise, total body fat increases in pre-pubertal children appear to be slowed by participating in structured physical activity of high or at least moderate intensity for at least one hour, twice per week. The slower rate of body fat accumulation is noteworthy by the structured activity groups, particularly as the population of children receiving no treatment ('CONT' group) within this study are accumulating fat at a rate in line with reference data provided by McCarthy *et al.* (2006). It also appears that participation in structured skill based activity for least one hour, two times per week may be most effective at reducing centrally distributed body fat. The positive effect that structured exercise programmes have on body fat indices occurred without any significant improvement of time spent in physical activity. Although disappointing from a broad health point of view, this finding suggests that the intervention alone was sufficient to minimise fat increases but insufficient in promoting increased participation in physical activity. It is possible that the physical activity performed at intervention sessions replaced rather than added to normal levels of physical activity.

6.4.3 Strengths and limitations

There are a number of strengths to this study; the design of the intervention programmes makes them easy to replicate in school environments. Both 'HIPA' and 'FMS' interventions were delivered as an after-school club, but could easily be integrated into physical education lessons during school time. Although the participation compliance was good in this study, had all intervention programmes been during the school day and therefore compulsory, like the 'PASS' programme (which had very good compliance rate) the effect of the interventions may have been greater and sample sizes may have been larger, increasing statistical power. The use of objective bone mineral, body fat and physical activity measures is also a key strength to this study.

There were also a number of limitations in the present study; despite compliance to activity sessions being good, the compliance to physical activity monitoring was problematic. There were low levels of compliance for full 7-day physical activity monitoring, although we successfully collected 3 week days of data for the majority of participants. Although physical activity patterns are different for weekday and weekend days (Riddoch *et al.*, 2007) and children are significantly more physically active during the weekend days (van Sluijs *et al.*, 2008); the present intervention programme took place during the week, rather than weekend, we therefore felt it acceptable to use the 3 week-day physical activity criteria. Subsequently, the interpretation of changes to body composition and bone with reference to physical activity discussed are subject to these physical activity criteria. As well as there being variability in PA data from day to day, another limitation of the PA data is that accelerometers cannot detect all activity, as subjects were advised to remove the accelerometer during any water based activity or full contact activity so not to incur damage or injury, and activity diaries were not kept.

The non-homogenous sample provided insufficient power to analysis the effect of the intervention by sex and is therefore another limitation to this study. The baseline characteristics showed that there were no sex differences at baseline and any maturational differences were accounted for within the analysis, which therefore provided rationale for pooling the samples. Additionally, diet was not controlled during the intervention, nor was it the main foci of this study; therefore it must be acknowledged that changes concerning body composition are not subject to any dietary intervention.

Finally, a follow-up study may strengthen the outcomes of this study, by measuring any changes in body fat and bone mineral changes and also time spent in habitual physical activity after the intervention. Ideally, a longitudinal study would provide information on the effect of continued physical activity programmes on children across the maturation stages.

6.5 Conclusions

All interventions had a positive effect on body fat by minimising fat mass accumulation. The most effective intervention was the 'HIPA' group, inferring that the high-intensity nature of the activity sessions was most effective at minimising body fat accumulation. The greatest magnitude of change in femoral neck BMC and BMD was also reported by the 'HIPA' group which is also likely to be attributable to the intensity of the weight-bearing activities in the HIPA programme.

This study assessed the effectiveness of three different physical activity interventions by measuring health indices objectively to provide accurate data on the effect of high-intensity programme, a skill development programme and lifestyle-based programme. The findings suggest that the

'HIPA' intervention was most beneficial to health outcomes, but neither intervention had significant effect on increasing time spent in physical activity. The outcome of this intervention was also linked to what the whole of England is trying to achieve through the policy of 2 hours of quality PE and an additional 2-3 hours beyond the school day delivered by a range of school, community and club providers through the PESSYP strategy (DCSF, 2008). The study was designed to provide a fun, pragmatic programme that can easily be integrated into school and are attractive to children.

The results are encouraging because participation in structured physical activity of a moderate or high intensity, which can easily be replicated in a school setting, has a positive effect on bone mineral accrual and total and abdominal body fat. . The between group analysis also indicates that exposure to either type of exercise intervention is more beneficial to health outcomes than no intervention.

Chapter

7

Synthesis of studies: General discussions, limitations and conclusions

7.0: Synthesis of studies: general discussions, limitations and conclusions

In this chapter the aims of the thesis will be revisited and the interpretation from results of the three studies will be discussed. Practical Implications from the findings will also be discussed as will the key limitations of the studies, finishing with the final conclusions.

The aim of this thesis was to investigate and evaluate the effect of different physical activity programmes on bone health and body composition in a representative sample of 9-11 year old children. The purpose of this study was to allow us to assess the impact a physically active lifestyle can have on protecting against or delaying obesity related risk factors and osteoporosis.

In the exploratory phase of this thesis (Study 1) it was found that beneficial bone mineral accrual and positive changes in body fat were evident from 9 weeks of a structured physical activity programme (STEX). Habitual physical activity, however, was not assessed over the short intervention period, which prevented clear conclusions over the effect the intervention had on physical activity as well as the associated risk factors.

The small correlational study highlighted the relationships between bone mineral, body fat and time spent in physical activity, which along with the feasibility study allowed us to confidently conduct the longer 12 month intervention study. The effect of the 12-month school based physical activity intervention programme, where three different programmes (delivered concurrently) were evaluated on their effectiveness on promoting positive changes in bone health, body composition, physical activity and cardio-respiratory fitness. Thus informing us of practices which could be used to help reduce the incidence of health-related risk factors.

7.1 Review of main findings

Study 1 showed that a short-term high- intensity structured activity (STEX) programme implemented in a primary school had a significant effect on increasing bone mineral accrual and had beneficial effect on body composition. Significant and clinically important bone mineral accrual was attained through high-impact vigorous activity performed for 60 min twice per week. Accelerated bone mineral increases and small but favourable changes in body composition were observed after the structured exercise intervention compared to the age-matched controls. This was essentially a feasibility study, which allowed us to trial aspects of the study before conducting a year long intervention. The programmes were feasible in school, we received positive feedback form parent and teachers regarding the logistics of after-school activity. From poor complience and feedback from parents/teachers and pupils we decided to change the PASS intervention for the 12 month intervention. The importance of a reward system was also discussed to reduce drop out in the 12 month study

The correlational study (study 2) highlighted the importance of high volume (over 90 min per day) and high intensity (PA_8) physical activity (over 10 min per day) as a precursor to high bone mineral status and low body fat in children.. The significant relationships strengthen the supporting argument for a higher recommended daily PA level (>90 min per day) and the promotion of high-intensity activity for positive health outcomes but the small scale nature of the study limits any direct causal associations drawn from this.

The 12 mnth study (Study 3) showed the greatest magnitude of change in femoral neck BMC and BMD was reported by the HIPA group which is likely to be attributable to the intensity of the weight-bearing activities in the programme. There was limited evidence of any significant changes in total body BMC or BMD over the 12 month intervention despite significant changes being observed in the 9-week exploratory study. Pubertal stage could be the confounding factor in this as the children in study 1 were more advanced, (with the median tanner stage of 3) than the children in study 3. Following study one, we chose to use the maturity offset prediction equation (Mirwald et al., 2002) to assess pubertal status in study 3. This was a less intrusive measure and was also less subjective than the self assessed Tanner stage method used in study 1. Despite this methodological difference, maturity was accounted for in the analysis and therefore maturation is unlikely to have had an effect.

All interventions had a positive effect on body fat by minimising fat mass and % body fat accumulation, though fat was not reduced by any intervention. The outcome still indicates that the introduction of physical activity, and whether high intensity, skill based or lifestyle based can produce favourable changes in body fat. The most pronounced effect was observed in the HIPA group, inferring that the high intensity nature of the activity sessions was most beneficial. Reductions in body fat are acknowledged in both intervention studies using obese childhood populations (Gutin *et al.*, 1999; 2002, Knopfli *et al.*, 2008), and those assessing "normal" population children (Gutin *et al.*, 2008, Martinez Vizcaino *et al.*, 2008). Differing study designs, methods of body fat assessment and designs of physical activity programme make it hard to draw clear comparisons.

Neither intervention programme had a significant effect on increasing time spent in physical activity. It could be that physical activity levels were displaced, by which children replace their normal physical activity with the physical activity in the intervention, rather than adding to it.

7.2 Implications of findings

Bone heath and body composition findings suggest that despite participants meeting the current daily PA guideline, the prevalence of low bone mass for age and high body fat warrant concern, particularly as physical activity is ordinarily associated with a positive effect of bone health and body composition. The evidence from the year long intervention supports the beneficial effect of high-intensity physical activity from the HIPA intervention as the most beneficial at promoting positive health outcomes including enhanced femoral neck BMC and BMD. Each intervention was designed to be easily integrated into schools, therefore from the outcomes of this thesis we would recommend the integration of a high- intensity activity focus in schools, ideally in physical education lessons. In addition to lessons, after school clubs (as part of the PESSYP strategy of 2 hours of PE plus 2-3 hrs school/club/community sport) should be focusing on activities that are high-intensity and weight bearing such as game sports, multi-activities, fitness and dance. Ideally, these after-school clubs should have club links with external clubs to promote long-term participation in physical activity. This club-link network exists through school sport partnerships in primary (4-11 years) and secondary (11-16 years) schools across Britain, but because participation in after school clubs is voluntary only a limited number of children can access it, due to parental control, child care etc. Therefore physical education lessons in primary and secondary school (which are compulsory, 2 hrs/week) should be as weight-bearing and physically intensive as possible in order to promote bone mineral accrual and minimise gains in body fat.

7.3 Limitations

Physical activity monitoring and analysis were a key limitation of this thesis; the compliance to monitoring largely due to children not wearing monitors for long enough (wear-time) in order to satisfy daily wear-time criteria of 9 hours. Where possible children were re-monitored in an attempt to gain physical activity data but a 100% monitoring rate was never achieved. The reward system put in place to help reduce the anticipated losses due to this omission. Feedback from the children, uncovered that the most common reason for insufficient wear time was that children took off the accelerometer during water based / contact activities and forgot to put it back on. The loss of data due to this disturbance is illustrated by the fall in numbers during analysis. Occasionally monitors were faulty or technical problems occurred during analysis. The compliance problems therefore had a knock-on effect when analysing physical activity data as we were forced us to chose weakened criteria for inclusion (3 days of at least 9 hours.day^{-1}), which ultimately reduces the reliability of the data.

7.4 Final Conclusions

The studies within this thesis have provided a unique insight in to the current , bone mineral status, body composition and physical activity level of 9-11 year old Liverpool school children and the effect different physical activity interventions have on bone health and body composition. The findings from this thesis conclude that the intervention that prescribed high-intensity physical activity had the most beneficial impact on bone health and body composition when compared to the controls. The quantity of physical activity and the time spent in high intensity activity warrants further investigation to quantify an optimal dose. The findings also highlight that 9-11 year old children remain largely overweight, despite achieving 60 min of PA per day.

7.5 Recommendations for further research

Having observed some of the beneficial effects of the interventions on the "normal" population of children, future research could investigate what the effect of similar interventions on more at risk populations, or perhaps in peri or post pubertal children. Ultimately the main reason for such research is to promote physical activity and encourage positive lifestyle behaviours to offset the prevalence of risk factors in later life, therefore ideally it would be useful to track a population of people throughout their life to measure a lifelong effect, but logistically and ethically this is problematic. Short term intervention studies on specific populations (overweight children) would be useful as there are a number of studies in the literature that focus on overweigh/obese populations. Short term studies within specific games sports would also be interesting, particularly looking at changes in bone density and body composition. We would also recommend that the inclusion of dietary analysis as an important factor to consider when assessing changes in body composition in future research.

Chapter

8

References

8.1 References

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Appendix A: Methods

A:1 Copy of DXA outputs

A:2 Calibration sheets DXA

Appendix B: Study 1

B:1 Tanner Maturation questionnaire

Appendix C: Study 2/3

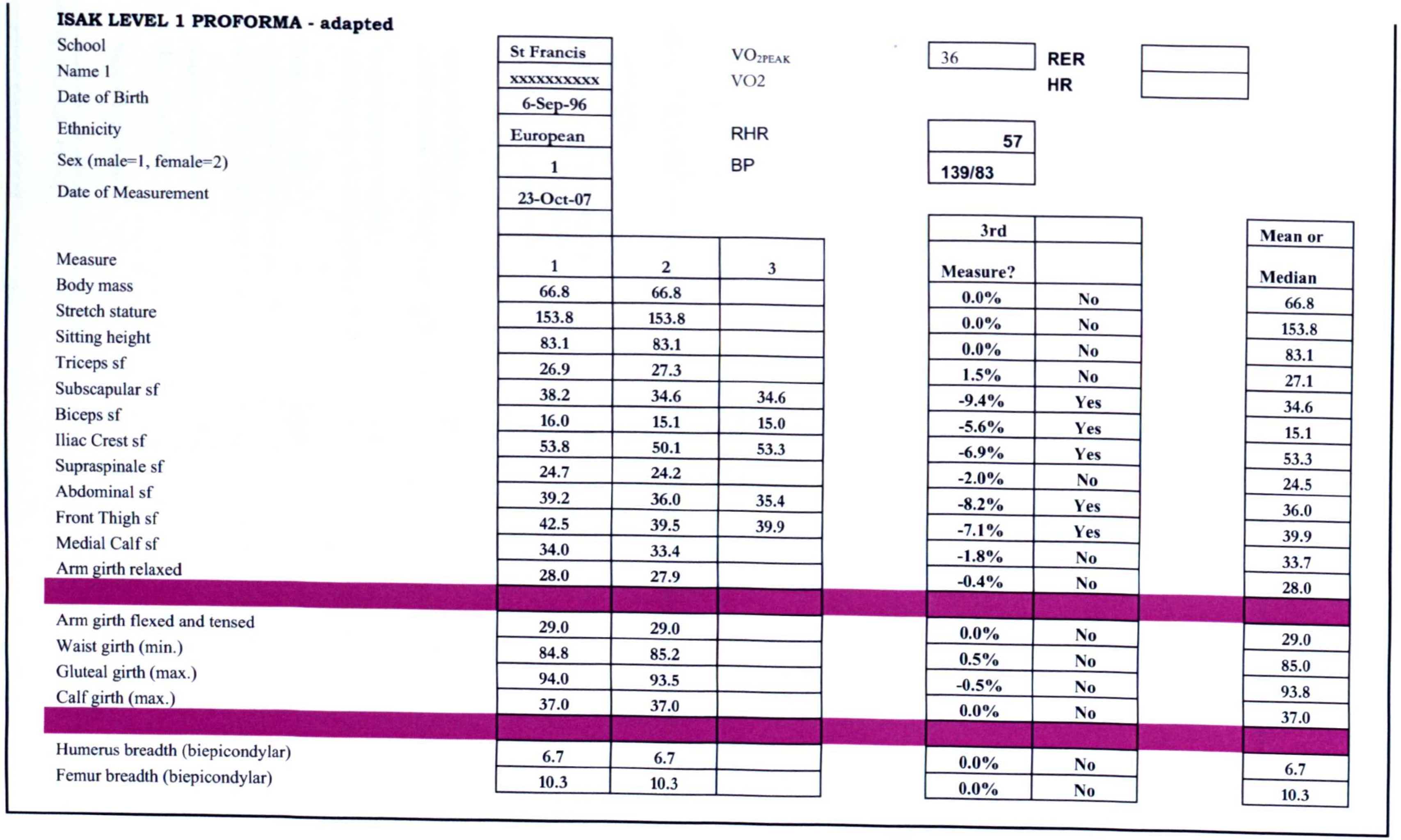
C:1 ISAK Excel sheet

C:2 Consort statement

C:3 Mean and SD for skin-fold data

C:4 Mean waist circumference and DXA derived trunk fat data from each time point

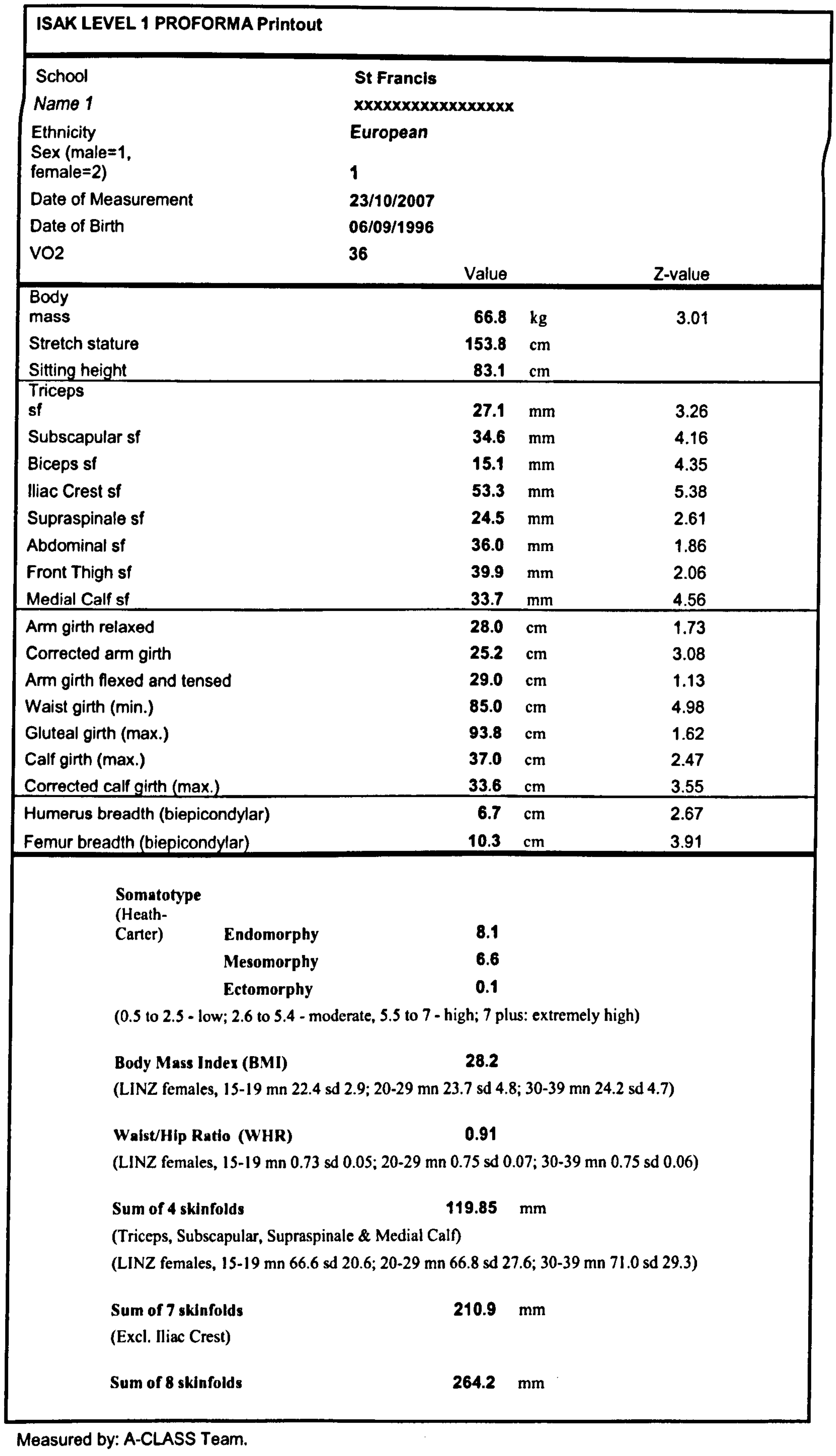
C:1. The following Excel sheets are anonymised examples of the ISAK data collection sheet used in skin-fold assessment



ISAK LEVEL 1 PROFORMA - adapted

School	St Francis	VO_{2PEAK}	36	RER	
Name 1	xxxxxxxxxx	VO2		HR	
Date of Birth	6-Sep-96				
Ethnicity	European	RHR	57		
Sex (male=1, female=2)	1	BP	139/83		
Date of Measurement	23-Oct-07				

Measure	1	2	3	3rd Measure?		Mean or Median
Body mass	66.8	66.8		0.0%	No	66.8
Stretch stature	153.8	153.8		0.0%	No	153.8
Sitting height	83.1	83.1		0.0%	No	83.1
Triceps sf	26.9	27.3		1.5%	No	27.1
Subscapular sf	38.2	34.6	34.6	-9.4%	Yes	34.6
Biceps sf	16.0	15.1	15.0	-5.6%	Yes	15.1
Iliac Crest sf	53.8	50.1	53.3	-6.9%	Yes	53.3
Supraspinale sf	24.7	24.2		-2.0%	No	24.5
Abdominal sf	39.2	36.0	35.4	-8.2%	Yes	36.0
Front Thigh sf	42.5	39.5	39.9	-7.1%	Yes	39.9
Medial Calf sf	34.0	33.4		-1.8%	No	33.7
Arm girth relaxed	28.0	27.9		-0.4%	No	28.0
Arm girth flexed and tensed	29.0	29.0		0.0%	No	29.0
Waist girth (min.)	84.8	85.2		0.5%	No	85.0
Gluteal girth (max.)	94.0	93.5		-0.5%	No	93.8
Calf girth (max.)	37.0	37.0		0.0%	No	37.0
Humerus breadth (biepicondylar)	6.7	6.7		0.0%	No	6.7
Femur breadth (biepicondylar)	10.3	10.3		0.0%	No	10.3



ISAK LEVEL 1 PROFORMA Printout

School	**St Francis**		
Name 1	xxxxxxxxxxxxxxxxx		
Ethnicity	***European***		
Sex (male=1, female=2)	**1**		
Date of Measurement	**23/10/2007**		
Date of Birth	**06/09/1996**		
VO2	**36**		
	Value		Z-value
Body mass	**66.8**	kg	3.01
Stretch stature	**153.8**	cm	
Sitting height	**83.1**	cm	
Triceps sf	**27.1**	mm	3.26
Subscapular sf	**34.6**	mm	4.16
Biceps sf	**15.1**	mm	4.35
Iliac Crest sf	**53.3**	mm	5.38
Supraspinale sf	**24.5**	mm	2.61
Abdominal sf	**36.0**	mm	1.86
Front Thigh sf	**39.9**	mm	2.06
Medial Calf sf	**33.7**	mm	4.56
Arm girth relaxed	**28.0**	cm	1.73
Corrected arm girth	**25.2**	cm	3.08
Arm girth flexed and tensed	**29.0**	cm	1.13
Waist girth (min.)	**85.0**	cm	4.98
Gluteal girth (max.)	**93.8**	cm	1.62
Calf girth (max.)	**37.0**	cm	2.47
Corrected calf girth (max.)	**33.6**	cm	3.55
Humerus breadth (biepicondylar)	**6.7**	cm	2.67
Femur breadth (biepicondylar)	**10.3**	cm	3.91

Somatotype (Heath-Carter)	**Endomorphy**	**8.1**
	Mesomorphy	**6.6**
	Ectomorphy	**0.1**

(0.5 to 2.5 - low; 2.6 to 5.4 - moderate, 5.5 to 7 - high; 7 plus: extremely high)

Body Mass Index (BMI) **28.2**

(LINZ females, 15-19 mn 22.4 sd 2.9; 20-29 mn 23.7 sd 4.8; 30-39 mn 24.2 sd 4.7)

Waist/Hip Ratio (WHR) **0.91**

(LINZ females, 15-19 mn 0.73 sd 0.05; 20-29 mn 0.75 sd 0.07; 30-39 mn 0.75 sd 0.06)

Sum of 4 skinfolds **119.85** mm

(Triceps, Subscapular, Supraspinale & Medial Calf)

(LINZ females, 15-19 mn 66.6 sd 20.6; 20-29 mn 66.8 sd 27.6; 30-39 mn 71.0 sd 29.3)

Sum of 7 skinfolds **210.9** mm

(Excl. Iliac Crest)

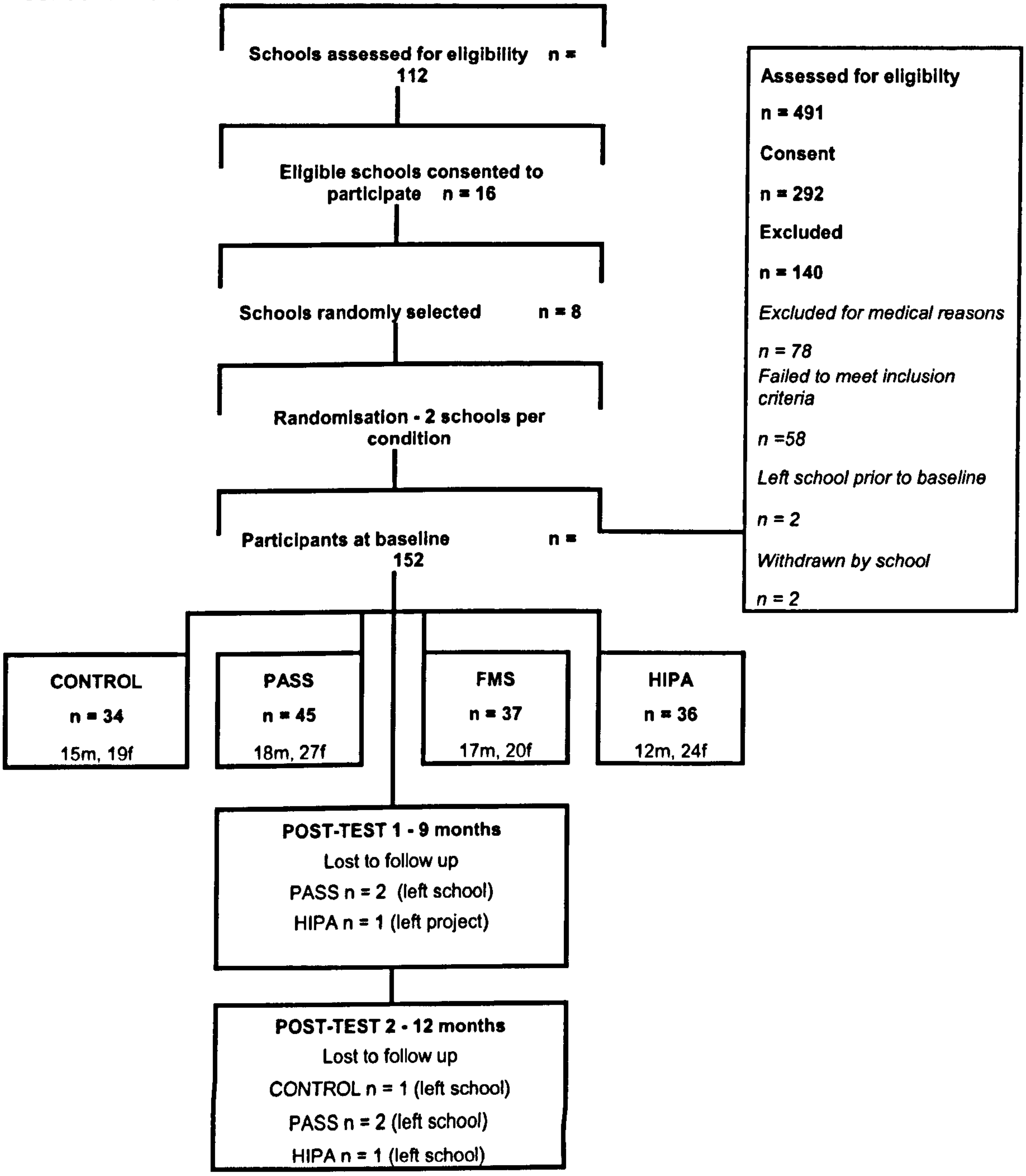
Sum of 8 skinfolds **264.2** mm

Measured by: A-CLASS Team.

C:2

Consort Statement

CONSORT EXCLUDING CHILDREN WITH MULTIPLE MISSING BASELINE MEASURES



C:3

Table C3.1. Sum (∑) of skin-fold data from baseline, mid-test (9 months) and post-test (12 months) by intervention group.

Sum of skin-fold measures		Baseline			Mid-test			Post-test		
		N	M	sd	*N*	M	sd	*N*	M	sd
∑4SF (mm)	CONT	*32*	53.76	25.30	*32*	53.32	22.25	*32*	56.33	22.04
	PASS	*44*	61.98	20.63	*43*	63.16	22.00	*41*	65.78	24.39
	HIPA	*36*	60.83	23.06	*35*	62.59	25.66	*33*	65.54	27.64
	FMS	*36*	46.14	20.85	*35*	42.97	21.09	*38*	46.16	22.26
∑7SF (mm)	CONT	*32*	103.33	47.00	*32*	102.50	40.70	*32*	105.60	40.00
	PASS	*44*	122.60	38.70	*43*	120.41	37.96	*41*	124.51	41.40
	HIPA	*36*	115.24	39.18	*35*	116.81	46.80	*33*	121.88	49.40
	FMS	*36*	89.39	41.39	*35*	82.09	39.98	*38*	87.78	41.77
∑8SF (mm)	CONT	*32*	118.82	53.91	*32*	122.20	51.56	*32*	121.02	45.46
	PASS	*44*	143.27	45.85	*43*	140.75	43.51	*41*	143.77	47.81
	HIPA	*36*	132.65	44.89	*35*	136.95	54.31	*33*	144.52	60.87
	FMS	*36*	103.06	49.27	*35*	95.46	47.15	*38*	101.63	49.88

Table C3:2. Raw skin-fold data from baseline, mid-test (9 months) and post-test (12 months) by intervention group

		Baseline			Mid-test			Post-test		
Skin-fold sites		***N***	**M**	**sd**	***N***	**M**	**sd**	***N***	**M**	**sd**
Tricep (mm)	**CONT**	*32*	15.69	4.77	*32*	15.44	4.80	*32*	16.49	4.73
	PASS	*44*	17.98	4.95	*43*	17.37	4.69	*41*	17.72	5.06
	HIPA	*36*	16.90	4.54	*35*	16.88	5.45	*33*	18.01	6.73
	FMS	*36*	14.44	5.11	*35*	12.90	4.94	*38*	14.23	5.16
Subscapular (mm)	**CONT**	*32*	10.69	7.09	*32*	11.07	6.46	*32*	10.85	5.42
	PASS	*44*	13.05	7.14	*43*	13.36	6.78	*41*	14.13	7.68
	HIPA	*36*	13.39	7.67	*35*	12.61	6.60	*33*	14.09	7.30
	FMS	*36*	8.85	4.12	*35*	8.65	4.92	*38*	9.57	5.94
Bicep (mm)	**CONT**	*32*	9.22	4.67	*32*	9.28	3.79	*32*	8.99	3.64
	PASS	*44*	10.83	3.52	*43*	9.66	3.25	*41*	10.20	3.60
	HIPA	*36*	11.21	4.02	*35*	10.31	4.72	*33*	11.10	4.30
	FMS	*36*	8.34	3.97	*35*	7.24	3.33	*38*	7.87	4.20
Illiac Crest (mm)	**CONT**	*32*	15.69	7.64	*32*	19.70	11.95	*32*	15.43	6.04
	PASS	*44*	20.92	8.40	*43*	20.34	8.04	*41*	19.27	7.33
	HIPA	*32*	19.92	8.69	*35*	20.13	8.44	*33*	22.27	12.02
	FMS	*36*	13.67	8.17	*35*	13.37	7.43	*38*	13.88	8.51
Supraspinale (mm)	**CONT**	*32*	11.52	8.24	*32*	11.50	6.54	*32*	12.72	6.97
	PASS	*44*	13.53	5.67	*43*	14.80	6.42	*41*	16.15	7.44
	HIPA	*36*	14.36	6.96	*35*	15.73	8.76	*33*	16.43	8.67
	FMS	*36*	10.02	6.60	*35*	9.61	6.58	*38*	10.25	6.81
Abdoman (mm)	**CONT**	*32*	16.39	9.47	*32*	17.43	9.59	*32*	17.88	8.89
	PASS	*44*	21.49	8.11	*43*	21.34	6.98	*41*	22.14	7.68

	HIPA	*35*	18.77	7.77	*35*	20.63	9.34	*33*	20.99	9.77
	FMS	*36*	14.38	9.89	*35*	13.71	9.48	*38*	14.75	9.94
Front Thigh (mm)	**CONT**	*32*	23.67	9.27	*32*	22.48	7.20	*32*	22.44	7.52
	PASS	*44*	27.95	9.89	*43*	26.25	8.57	*41*	26.43	8.76
	HIPA	*36*	24.66	8.71	*35*	23.61	8.87	*33*	24.26	9.60
	FMS	*36*	20.53	7.88	*35*	18.16	7.42	*38*	19.02	6.86
Medial Calf (mm)	**CONT**	*32*	15.70	6.80	*32*	15.32	5.70	*32*	16.36	6.56
	PASS	*44*	17.36	5.59	*43*	17.63	6.31	*41*	17.88	6.77
	HIPA	*36*	16.04	5.94	*35*	17.04	6.98	*33*	16.81	6.48
	FMS	*36*	12.82	5.80	*35*	11.81	5.39	*38*	12.21	5.15

Table C3.3. Raw girth and bone breadth data from baseline, mid-test (9 months) and post-test (12 months) by intervention group

		Baseline			Mid-test			Post-test		
Girths & Breadths		*N*	M	sd	*N*	M	sd	*N*	M	sd
Arm relaxed	CONT	*32*	21.35	2.99	*32*	22.13	3.25	*32*	22.70	3.35
	PASS	*44*	23.09	2.66	*43*	24.17	2.94	*41*	24.60	3.09
	HIPA	*36*	23.19	2.42	*35*	23.93	2.70	*33*	24.27	2.68
	FMS	*36*	20.53	2.97	*35*	21.02	3.00	*38*	21.81	3.10
Arm tensed	CONT	*32*	22.14	2.87	*32*	22.87	3.25	*32*	23.17	3.17
	PASS	*44*	23.87	2.72	*43*	24.49	2.80	*41*	25.04	2.98
	HIPA	*36*	23.89	2.53	*35*	24.39	2.49	*33*	24.85	2.62
	FMS	*36*	21.57	2.98	*35*	21.92	3.00	*38*	22.51	2.81
Waist	CONT	*32*	61.22	7.41	*32*	61.44	7.62	*32*	63.89	7.98
	PASS	*44*	64.73	6.59	*43*	67.45	7.00	*41*	68.26	7.91
	HIPA	*36*	65.35	7.02	*35*	66.94	7.47	*33*	68.17	7.86
	FMS	*36*	59.68	7.30	*35*	61.16	7.54	*38*	62.26	7.68
Gluteal	CONT	*32*	74.20	8.33	*32*	74.34	8.56	*32*	76.72	9.78
	PASS	*44*	77.83	7.01	*43*	79.83	7.79	*41*	81.93	7.72
	HIPA	*36*	78.44	6.48	*35*	80.15	6.78	*33*	81.36	6.27
	FMS	*36*	71.08	7.62	*35*	72.71	7.31	*38*	74.08	7.99
Medial Calf	CONT	*31*	28.37	3.11	*32*	28.88	3.19	*32*	29.44	3.30
	PASS	*44*	29.97	2.61	*43*	30.59	2.78	*41*	31.17	2.85
	HIPA	*36*	30.01	2.71	*35*	30.98	2.78	*33*	31.24	2.44
	FMS	*36*	27.41	2.87	*35*	28.05	2.94	*38*	29.48	5.70
Humerous epicondyle	CONT	*31*	5.63	0.40	*32*	5.75	0.42	*32*	5.74	0.39
	PASS	*44*	5.71	0.39	*43*	5.91	0.38	*41*	5.87	0.40
	HIPA	*36*	5.89	0.65	*35*	6.55	3.92	*33*	5.92	0.68
	FMS	*36*	5.52	0.42	*35*	5.58	0.40	*38*	5.65	0.42

Femur epicondyle	**CONT**	*31*	8.40	0.67	*32*	8.46	0.69	*32*	8.66	0.72
	PASS	*44*	8.55	0.75	*43*	8.79	0.63	*41*	8.97	0.69
	HIPA	*36*	8.44	0.75	*35*	8.62	0.74	*33*	8.75	1.05
	FMS	*36*	8.20	0.55	*35*	8.31	0.59	*38*	8.50	0.60

C:4

Group Statistics		**CONT**			**PASS**		**HIPA**			**FMS**		
	Sex	N	Mean	SD	Mean	SD	N	Mean	SD	N	Mean	SD
Waist circ (cm) Baseline	Girl	18	59.4	7.5	64.0	6.5	24	64.8	6.1	19	59.1	6.1
	Boy	15	64.2	7.1	65.9	6.7	12	66.5	8.8	16	59.5	8.1
Waist circ (cm) 9 mon	Girl	18	59.5	6.9	66.6	7.0	24	66.1	6.6	18	61.4	6.4
	Boy	14	64.0	7.9	68.8	7.0	11	68.7	9.2	17	60.9	8.8
Waist circ (cm) 12 mon	Girl	18	62.5	8.0	67.0	8.1	23	67.2	7.2	20	61.4	6.3
	Boy	15	66.4	8.1	70.2	7.4	10	70.4	9.2	17	62.5	8.8

Group Statistics		**CONT**			**PASS**			**HIPA**			**FMS**		
	Sex	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Trunk fat mass (g) Baseline	Girl	19	3450.1	2080.1	26	4745.9	2575.4	26	4745.9	2575.4	19	3179.6	1477.6
	Boy	13	3476.0	1953.7	16	3948.9	1866.3	16	3948.9	1866.3	16	2502.6	2248.9
Trunk fat mass (g) 9 mon	Girl	18	3984.4	2609.9	26	5049.2	2743.7	26	5049.2	2743.7	18	3456.7	1538.9
	Boy	14	3501.8	2098.7	17	4324.6	1908.1	17	4324.6	1908.1	17	2553.2	2399.7
Trunk fat mass (g) 12 mon	Girl	18	4067.2	2545.0	25	5377.5	3131.7	25	5377.5	3131.7	20	3717.0	1810.9
	Boy	15	4223.8	2482.0	16	4813.7	2034.9	16	4813.7	2034.9	17	2716.1	2447.0

Appendix D: Study 3

D:1 HIPA session examples

D:2 FMS session examples

D:3 PASS mission examples

D:1 HIPA (1)

School:

Coaches:

Date:

Indoor/Outdoor:

	Time	Activity	Equipment
WU	5min	*Stuck in the mud: 2 children 'on' who have to tag other pupils within specified space (hall/playground). When tagged, pupils are 'stuck' until they are set free by fellow pupil running under arms.*	*Bibs*
	2min	*Dynamic stretches*	*n/a*
Main	15min	*Coconut island: 4 hoops represent islands, deflated balls represent coconuts, there is one coconut in each island. 4 pupils are selected as sharks who protect their island and the coconuts on them. The rest of the pupils are swimmers who's aim is to steal the coconuts from the island without getting tagged 'bitten' by a shark. If a swimmer is tagged, they have to go to Hopsital with 'shark bite'. Hospital is a bench in the corner of the hall/playing area where swimmers have to perform step-ups. Only when a coconut is successfully stolen, can a person come out of hospital.*	*Hoops x 4, deflated balls x4*
	15min	*Endzone: 2 teams, invasion game, the aim is for one team to pass the ball down the court/pitch and for it to be caught by one of their team in the oppositions goal. Players are not allowed to run with the ball.*	*Cones, ball (Bball or soft rugby) x 2, Bibs*
	10min	*Sharky Sharky: 2 sharks, the rest of pupils are fish. Sharks have to try and tag fish. On command, the fish have to run to the other side of the hall/area without getting tagged by a shark. If they are tagged they turn into seaweed. Seaweed cannot move and are stuck where they got tagged, seaweed can also catch fish. The last 2 fish to be caught are the winners and are the sharks in the next game.*	*Cones*
CD	5min	*Circle chase*	*n/a*

Comments

D:1 HIPA (2)

School: **Coaches:**
Date: **Indoor/Outdoor:**

	Time	Activity	Equipment
WU	5min	Wasps: 3 children 'on' who are the wasps, they have small sponge balls - which are the stings. They have to trhow the balls ate the other pupils, of it hits them below the waist, they have been stung, and they must stand still and call for first aid, they are set free by fellow pupil running under arms.	Bibs
	2min	Dynamic stretches	n/a
Main	10min	NSEW and the pirate game: Instructor calls north, south ,east or west and pupils have to run to that place. last pupil there gets a forphit. instructor also uses command style and shouts: climbing the rigging, boom coming over, scrub the decks, abandon ship!, shark attack!! etc... and the pupils do the apprporiate action.	n/a
	15min	Bean bag races: 4/5 teams, in lines at one end of the space. for each team, 4 bean bags are placed 5m apart from each other in row. The first pupil in each team runs to collect the first bean bad and brings it back to the team, then runs to get the second bean bag and brings it back, this is repeated until all are back, then the nect person in the team puts them out agaian and so on until all pupils have run, the first team back to complete wins.	Cones, bean bags x 20
	10min	Obstical Relays: in same teams as before, various obsticles placed for pupils to accomplish, and return to tag next pupil in the relay.	Cones, skipping ropes, hopskotch.
CD	10min	Ball chase: 2 teams, one team stand in circle and pass the ball aronund circle as fast as possible, counting number of passes. They have to try and get as many passes as possible before the other team run round the circle one by one, in a relay. Once all players ahve run the team shout STOP! and the team tell them how many passes where made. the teams then swap and try to beat the score. the faster the team runs, the less time the team in the circle have to pass.	Ball. Cones.

Comments

D:2 FMS (1)

School: **Coaches:**

Date: **Indoor/Outdoor:**

Focus: Dodge

	Time	Activity	Equipment
WU	5min	Stuck in the mud: 2 children 'on' who have to tag other pupils within specified space (hall/playground). When tagged, pupils are 'stuck' until they are set free by fellow pupil running under arms.	Bibs
	2min	Dynamic stretches	n/a
Main	10min	Dodging in and out of cones: Cones set up in slight zig-zag, pupils in small groups have to practice dodging in and out of the cones, with a focus on pushing off the outside leg to gain power and speed. Instructor demo before pupil practice. Task can be developed by adding a competitive element to it.	Cones
	10min	Dodge cones: in pairs, each pair has 4 cones, 2 cones plaved about 2 m apart, with the other cones placed about half a meter to the outside of the ooriginal cones. The pupils stand opposite each other, one pupil is A and the other B. A has to dodge tap the outside cone, the opponent has to read the dodge and try to tap the inside cone before A reaches the outside cone.	Cones, ball (Bball or soft rugby) x 2, Bibs
	10min	Run the guantlet: Cones are used to form a tunnel (8 on each side), 8 pupils then stand on the lines created bythe cones. The other pupils in a staggered approach have to run using the dodge through the tunnel, but they have to dodge their way past the pupils in the tunnel.	Cones
	10min	Sharky Sharky: 2 sharks, the rest of pupils are fish. Sharks have to try and tag fish. On command, the fish have to run to the other side of the hall/area without getting tagged by a shark. If they are tagged they turn into seaweed. Seaweed cannot move and are stuck where they got tagged, seaweed can also catch fish. The last 2 fish to be caught are the winners and are the sharks in the next game.	Spots
CD	5min	Recap on fundementals of Dodge	n/a

Comments

D:2 FMS(2)

School: **Coaches:**

Date: **Indoor/Outdoor:**

Focus: Kick

	Time	Activity	Equipment
WU	5min	*Wasps: 3 children 'on' who are the wasps, they have small sponge balls - which are the stings. They have to trhow the balls ate the other pupils, of it hits them below the waist, they have been stung, and they must stand still and call for first aid, they are set free by fellow pupil running under arms.*	*Sponge balls*
	2min	*Dynamic stretches*	*n/a*
Main	10min	*Target ball: Cones are up in a triangle formation, from a marked spot, pupils have to strike the ball (kick) aiming for the cone at the apex of the triangle, if it hits the cones they get 5 points, depending on where the ball goes, they will get 4, 3, 2 or 1 points.*	*Cones, footballs*
	5min	*Striking practice: pupils in small groups, shooting at goal but have to hit it from a certain distance (say 15yards) - depending on ability, ensure that they were hitting for power. Focus on hitting ball with the front part of the foot and to follow through with kicking leg.*	*Cones, footballs*
	10min	*Beat the keeper: in 3's, 2 strikers and one keeper. Strikers stand opposite each other with keeper in the middle (standing on goal line, between 2 cones. Striker A kicks the ball, if it foes in, the ball rolls to striker B, who then trys to kick it in the goal beating the keeper, if the keeper saves the ball , the ball goes to the other side. Pupils alternate roles frequently.*	*Cones, footballs*
	10min	*Goalies and strikers: pupils are divided into 4 groups that stand in each corner of the room/space. They are numbered 1-5. The instructor called a number and all pupils who are that number run out and have to get possessions of the ball and score a goal, whislt the other team have to try and stop them, there is no goalkeeper.*	*Football*
CD	5min	*Recap on fundementals of kick*	*n/a*

Comments

D3: PASS outline of missions

Mission	Outline of mission
Block one. Oct ’06 – Dec ’06 The children were encouraged to:	
Map drawing	Draw a map of the local area and house
Pedometer challenge	Write down how many steps that they had achieved each day
New activities	Think of activities that they could do around the house.
TV monitoring	Monitor how much television that they watched in a day.
Intelligent viewing	Reduce their television viewing to two hours a day,
Replacing TV with activity	Replace television viewing with physical activity and also to reintroduce pedometer challenge.
Break. Dec ’06 – Feb 07.	Focus groups with parents and teachers were undertaken.
Block two. Feb ’07 – April ‘07	
Photograph challenge	Disposable camera’s were issued to take pictures of active places
New game	To design own game and take pictures of this game.
Active Transport	Encouraging the children to use active transport
Energy balance	Children rated food they ate and activity they did, and asked does it balance?
Reducing screen-watching	The children were asked to reduce computer use as well as TV watching
Break. April ’07 – June ‘07	Focus groups with parents and teachers were undertaken.
Block three. June 07 – July 07	
60 minutes of activity	Points were given for each minute of activity that was undertaken.
Fitness Challenge	Children timed themselves doing physical activity tasks
Scavenger Hunt	To find certain household items in the quickest time they could
Whatever	Children were told that they could do whatever they wanted
Decisional balance	Choice between being active or sedentary in different situations
Break. July ‘07 – Sept ‘07	Focus groups with parents and teachers were undertaken.
Block four. Sept 07 – Oct 07	
Design own mission to increase activity x2	Children were issued with a few rules to design their own missions for 2 weeks.
Design own mission to decrease sedentary behaviour	Children were issued with a few rules to design their own missions
Advocacy poster	Children were asked to draw a poster based on their choice between physical activity and sedentary behaviour.

D3: Examples of missions:

Scavenger Hunt

The aim of the scavenger hunt is to find the household items on the mission in the quickest time possible. Each child was given a number of scavenger hunts to complete to help them gain 60 minutes of activity a day. The child was encouraged to ask a member of their family to time them, in order to include them.

SCAVENGER HUNT

Time started:

Item 1: comb

Item 2: toothpaste

Item 3: mug

Item 4: remote

Item 5: book

Item 6:

Time completed:

Pedometer Challenge

Every one who took part in PASS was given a pedometer. This mission asked the children to wear the pedometer every day for a week and to chart how many steps they did each day. The aim was to beat their previous day total and to try and get at least 10,000 steps. As well as encouraging children to be active this would also highlight to them and their family how many steps they do or don't do.

PEDOMETER CHALLENGE

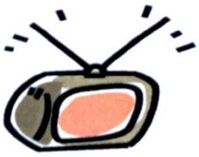
Write in the number of steps you do each day in the table below
At the end of each week add up your daily number of steps
Remember to reset your counter every day.

DAY	TUES	WEDS	THUR	FRI	SAT	SUN	MON
Number of steps							

Reducing screen watching

This mission asked the children to try and reduce the amount of time they spend watching television and playing on the computer. They were encouraged to do this by replacing these sedentary behaviours with activities of their choice and to use intelligent viewing. This is where the children are to choose their favourite programmes to watch and to turn off when there is something on that doesn't really interest them. The children had been given examples of activities to do in a previous mission.

REDUCING SCREEN WATCHING

	Monday	Tuesday	Wednesday	Thursday
TV 				
Computer 				
Activities				
Steps				