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**Fundamental movement skills, physical activity and weight status in British school children**

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# Fundamental Movement Skills, Physical Activity and Weight Status in British School Children.

By

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# Fundamental Movement Skills, Physical Activity and Weight Status in British School Children.

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### April 2015

**Supervisory team: Dr Samantha Birch, Professor Michael Duncan and Professor Rob James**

*A thesis submitted in partial fulfilment of the University's requirements for the Degree of Doctor of Philosophy*

# Dedication

I would like to dedicate this to my godmother Su Joyce for your love and financial support throughout. Without your kindness I would not of been able to spend as much time and energy on my PhD and would truly not have been able to do this without you. Thank you.

# Acknowledgements

## Declaration

This thesis makes a unique contribution to the literature for several reasons. Firstly, this thesis assesses the Fundamental Movement Skill (FMS) mastery levels of children in England; this had not been previously established. The research in this thesis determines the association between FMS and PA and elucidates at which time points FMS is best associated with a child's current PA levels, which previous research has been unable to conclude (Okley et al., 2001 and Mckenzie et al., 2002; Graf et al., 2004; Barnett et al., 2008; Hume et al., 2008). This thesis develops and extends Stodden et al's (2008) conceptual model to offer further understanding between the relationship of FMS, PA and weight status in an original way. A unique intervention was trialled that modified the content of Physical Education (PE) to offer what statutory PE currently does not. This was to identify if FMS could be taught, learnt and developed, if PA could be increased and sustained, and if physical self-perception could be improved during and following an ecologically valid intervention.

# Abstract

Introduction: Fundamental movement skills (FMS) form the prerequisite for sporting and physical activities (Gallahue and Ozmun 2002). Research has attempted to understand this relationship between FMS and physical activity (PA) (Cliff et al., 2009). Method: Following institutional ethical consent for each experimental study, three primary schools from the same electoral wards in Coventry were used throughout this research. Children were assessed subjectively on eight FMS, objectively on two FMS, height, body mass, skinfold thickness, habitual PA and physical self-perception. Additionally children were involved in a six week PA intervention with the aim of teaching and developing children's FMS and increasing PA and physical self-perception. Statistics Package for Social Science (SPSS) was used to analyse results throughout this research. Results: significant inconsistencies were noted in FMS development throughout age (MANOVA, $p<0.05$); significant gender bias was noted between specific FMS (MANOVA, $p<0.05$); significant negative correlations were found between weight status and specific FMS (Pearson's product, $p<0.05$); a combination of previous and current FMS mastery best predict current habitual PA level; FMS, PA, weight status and self-perception can be positively influenced via a six week PA intervention. Conclusion: the importance of children mastering FMS at an early age is associated with PA levels during childhood. Furthermore, effective methods of teaching FMS have become apparent and further research should focus on this to influence PE policy and the teachers in the UK.

## Presentation of results

Results of the present research have been published in peer reviewed journals and presented at international conferences.

Chapter 4 - **How does age, gender and weight status affect FMS mastery level in British Primary school children?**

- **Bryant, E.,** Duncan, M., and Birch, S. (2013) Fundamental Movement Skills and Weight Status in British Primary School Children. *European Journal of Sports Science*, 14 (7):730-736

- **Bryant, E.,** Duncan, M., Birch, S. (2012) The Relationship between Year group, Gender and Weight Status on the Mastery Level of Fundamental Movement Skills. Poster presentation at European College of Sport Science, Bruges (July 2012).

- **Bryant, E.,** Duncan, M., Birch, S. (2013) The Effect of Body Mass Index and Body Fat Percentage on Fundamental Movement Skills (FMS). Poster presentation at European Congress of Obesity, Liverpool (May 2013).

Chapter 5 - **Is current FMS a better predictor of current or future PA levels and weight status in British primary school children?**

- **Bryant, E.**, James, R., Birch, S., and Duncan, M. (2014) Does prior or current FMS predict future habitual physical activity (PA) levels and weight status? *Journal of Sports Science,* 32(19):1775-82

- **Bryant, E.,** Duncan, M., Birch, S, James, R. (2013) Fundamental Movement Skills (FMS) – A 1 year follow up.  Oral Presentation at the British Association for Sport and Exercise Science, University of Central Lancashire, Preston (September 2013)

Chapter 6 **- Can FMS mastery be increased through a 6 week physical activity intervention and does that intervention have positive effects on PA and weight status?**

- **Bryant, E.,** Duncan, M., Birch, S., James, R. (2014) A 6 week intervention to increase Fundamental Movement Skills mastery level and physical activity. Oral Presentation at European College of Sport Science, Amsterdam (July 2014).
- **Bryant E.,** Duncan, M. Birch, S. James, R. (2014) Fundamental Movement Skills, Self-Efficacy and Physical Activity in Overweight and Obese Children. Submitted for Poster Presentation at Association for the study of Obesity, Birmingham (September 2014).

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# List of Abbreviations

AMC – actual motor competence

BF% - body fat percentage

BMI - body mass index

DoH – Department of Health

FMS - fundamental movement skills

HRF – health related fitness

ISAK – International Society for the Advancement of Kinanthropometry

IQ – Intelligence Quotient

LDL – low density lipoprotein

M – mastery

MC – motor competence

MV – moderate to vigorous

MVPA – moderate to vigorous physical activity

NCPE – national curriculum for physical education

NM – near mastery

NO – non mastery

PA – physical activity

PE – physical education

PMC – perceived motor competence

POC – process orient checklist

PPSCS – perceived physical competency scale for children

QCA – Qualifications and Curriculum Association

SES – socio economic status

SPSS – statistical package for social sciences

WHO – World Health Organisation

# 1.0 Introduction

## 1.1 General Introduction

Trends show that children in the UK are becoming less active and fewer children are meeting the recommended guidelines for health enhancing PA (Craig et al., 2008). It has been suggested that this drop in PA level is one of the main causes of the rising obesity levels seen in the UK (Foresight, 2008). Obesity costs the NHS over £5 billion per year due to the physiological and psychological effects of being at this level of overweight (DoH, 2013).

In an attempt to understand a potential mechanism for this decreasing PA level the relationship between motor development and PA have been examined (Barnett et al., 2008; Hume et al., 2008; Cliff et al., 2009). Motor development is a phenomenon (McMorris, 2004) that has been the focus of many research studies for over 200 years (Cairns, 1988). Motor development is a process that every individual goes through to allow them to perform everyday activities. However, it is the FMS that have been examined to identify a relationship with PA and weight status throughout research. FMS are the basic primary skills that are initially learned and developed, and are required to act as the foundations for successful execution of sporting and physical activities (Gallahue and Ozmun, 2002). If these basic skills are not mastered, the development of the larger and more sports specific skills will be hindered (Gallahue and Ozmun, 2002). Therefore, if children have not developed the skill set to successfully partake in PA they may be more likely to drop out and not maintain a healthy PA level which will in turn affect

weight status. Research has suggested that the motor development of FMS is not a natural process and will need to be taught and practiced by children to gain mastery of these skills (Haywood and Getchall, 2002). Research has focussed on assessing the development of the FMS to understand its link with PA participation (Barnett et al., 2008; Hume et al., 2008; Cliff et al., 2009). Whilst research has attempted to understand the relationship between FMS, PA and weight status, there are gaps and inconsistencies in the literature that need to be addressed. These include a general lack of data on children in the UK, limited research on the association with present or future PA levels from FMS competency. Information on whether it is possible to teach and develop children's FMS level through a relatively short and practical physical education (PE) intervention is lacking in the UK literature base. The research in this thesis will aim to address these gaps highlighted within the literature which is discussed in more depth in chapter 1.5. If this link between FMS, PA and weight status can be further understood, then issues highlighted above can be further addressed. The results from the research in this thesis could: 1) potentially be important in influencing future interventions and policies in UK school PE provision, which in turn may help to target the declining PA levels seen in the developed world, particularly in the UK (Craig et al, 2008) and potentially provide useful information for future PE policy to meet the primary aim of PE; 2) to provide children with the skills and tools to lead an active lifestyle (QCA, 2007).

## 1.2 Motor development

The definitions of motor development have progressed in line with the expanding research in this area (Cairns, 1988). Roberton (1989) described motor development as the study of lifespan change in motor behaviour. More recently Haywood and Getchell (2009) have defined motor development as the sequential continuous age-related process whereby movement behaviour changes. The study of motor development has been reported since 1787 (Cairns, 1988) and will progress as long as technology/equipment and research advances, with definitions of this phenomenon continuing to develop. An example of one way in which advancements in technology will contribute to the study of motor development is the use of three dimensional motion camera analysis to assess motor skills (Galli et al., 2010). Being able to analyse different angles of joints simultaneously, could potentially highlight new information in regards to the patterns of motor development.

Although there are certain stages and milestones of motor development that a child will go through, each child will develop at different rates (Holbrook and Keonig, 2000). The very first signs of motor development are extensions in the upper spine, which can be detected in the foetus, via ultra sound, after five to six weeks of pregnancy (Malina, 2004). When a foetus is in the womb, impulsive movements are a common place for the development of muscles and joints before birth. Once born, the child's motor responses are a progression to those learnt in the womb and are influenced by two main factors; growth/maturity characteristics (morphological, physiological and neuromuscular) and the environment the

child is raised in. A combination of the two latter factors will determine a child's motor repertoire. Malina (2004) has suggested five sub categories (neuromuscular maturation; physical growth and behaviour characteristics; tempo of physical growth, biological maturation and behavioural development; residual effects of prior movement experiences; and new movement experiences) which all interact with each other and contribute to the motor development process. Therefore, the degree of interaction between the sub categories will result in different levels of motor development and in turn differing competency levels of FMS between children. In the first two years of life, postural, locomotor and prehensile control is gained. McGraw (1975) describes this as the development of the phylogenetic motor behaviours, for example learning to sit up, stand and walk. McGraw (1975) explains the latter as being characteristics of the human species that are required for normal functioning, which are less affected by practice. In contrast to this, skills that are characteristics of the individual and are more subject to practice are known as ontogenetic skills (McGraw 1975), for example skills such as throwing, catching and kicking. These are the skills that form the building blocks for sporting and physical activities. Gallahue and Ozmun (2002) have identified eight FMS as being the main skills that will underpin sporting and physical activities. There are three locomotor skills (running, hopping and galloping), three object control skills (catching, kicking and throwing), jumping and balance.

### 1.2.1 Control of Movement

Humans primarily control their movements through their neural interconnections between the brain, central nervous system and muscles (McMorris, 2004; Fairbrother, 2010; Edwards, 2011). As movements develop, these interconnections become streamlined and the performance of these movements is enhanced (McMorris, 2004).

Fairbrother (2010) identified six basic sources of sensory information that are used to control movements. These are described below.

- **Vision**: this is used to gain a primary source of information. It gives information such as direction, depth, environmental cues/characteristics and visual targets.

- **Hearing**: verbal feedback, communication and sound feedback are how humans can use hearing as a method to control their movements.

- **Balance**: gives information on the body's position and orientation. Balance is used in virtually every skill, and when the body detects an 'off balance,' muscles will be activated to make an adjustment to maintain balance.

- **Touch**: gives feedback information such as, pressure, temperature, shape, texture and movement.

- **Proprioception**: gives feedback information on the position of limbs, without the use of visual sense.

- **Kinesthesis**: gives information about the movement of multiple limbs and the speed at which they are moving.

Although the six senses are described individually, Fairbrother (2010) stresses the importance of how all the senses will integrate to control a movement. When controlling movements, different combinations of the six senses will be used. The challenge is, having to identify and select the most appropriate combination of sources to use for different skills/movements. Furthermore, it is not only selecting the source, but some sources such as hearing is involuntary and it takes discipline to respond to the most appropriate ones. This process is enhanced with practice. Furthermore, Kelso (1982) identifies that there are two ways in which people can use these senses to feedback on the successfulness of a performance. The first is continuous feedback control, often referred to as closed loop control. This is used in skills that are long or continuous in performance. Whilst executing the skills, continuous feedback allows time for the senses to be activated to give feedback on any muscular corrections that need to be adjusted in order for the movement to be successful. According to the information processing stages (Schmidt and Lee 2011); three corrections per second can be made during the performance of a continuous skill (Fairbrother, 2010). The second method identified is no-feedback control (also known as open loop control). This is used for very rapid skills that would not have time for continuous feedback. This method is used to assess the conditions of the situation, identify the movement goals and decide on the pattern of movements needed to achieve this goal (this is known as a motor programme; Schmidt and Wrisberg (2008). Once the skill has been completed immediate feedback is given through the appropriate senses, which will be considered for subsequent performances of the rapid execution of the skill. Again,

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Fairbrother (2010) stresses that the use of both continuous and no control feedback is essential for successful execution of movements.

## 1.2.2 Methods of skill acquisition

There are several methods that can be adopted to teach motor skills. These methods are described in this section and once more it is important to remember that a person will often use a combination of methods to learn a new skill (Schmidt and Wrisberg, 2008).

Explicit learning is thought of as the most common way to learn a new motor skill. It involves the person being fully aware that they are trying to learn a new skill and they are given a specific set of instructions. In contrast to this, implicit learning is when a person unconsciously learns a new skill (Magill, 2001). Although implicit learning can be effective it can sometimes result in the wrong technique of the skill being learnt, with the consequence of having to re-learn the skill explicitly, which overall could take longer (Fairbrother, 2010).

The most effective and commonly used method for learning a new skill is physical practice. It is where the saying 'practice makes perfect' is derived from. A subcategory in physical practice is to use part practice. This involves breaking down the skill into smaller components and perfecting each part before executing the skill as whole. However, when separating a skill in to smaller components, this can change the overall motor pattern of the whole skill.

The observational learning method must be supported by explicit learning as a person will be aware that they want to learn a skill by imitating a model, person or demonstration. Observation will then be supported by physical practice as the person will want to attempt what they have observed (McCullagh and Meyer, 1997). Research has identified that humans possess 'mirror neurons' that are activated when performing a skill and again when observing only that skill (Gazzola et al., 2007). Suggesting that humans are predisposed to learn new skills through observations. By using observations, patterns of coordination and timings can be learnt.

### 1.2.3 Cognitive theories of learning

The methods described in section 1.2.1 on 'Control of movement' were used by many psychologist/behaviourists to develop theories on how humans learn different motor skills/patterns. The main theories that are discussed in this research are reviewed below.

### 1.2.3.1 Fitts and Posner (1967)

This is a three stage theory that explains the process someone will go through when learning a new skill. The first stage is the cognitive stage; this involves the person making sense of the instructions, verbalising cues, taking in irrelevant cues and often making mistakes. After practice and time (time is dependent on the complexity of the skill being learnt), the performer will then move into the associative stage. In this stage less instructions and

verbalisation of cues are needed, and skills are performed successfully more times than not, however practice is still needed in this stage. Once the performer can execute the skill without needing any instructions and it becomes 'automatic', they have reached the autonomous stage. The length of time spent in each stage will be dependent on the complexity of the skill. However, once someone reaches the autonomous stage of learning, it is hard to alter the movement pattern of that skill. Therefore, if a bad habit is picked up and a performer enters the autonomous stage with the incorrect technique it can be very difficult to change.

A practical example of the three stage theory is based on an over arm throw;

Cognitive stage: observations of the correct technique will be made, and the coaching points will be clearly identified by a coach and attempted by the performer. This would include; stand side on to target, throwing arm would be the arm furthest away from the target, step towards target with the opposite leg to throwing arm, arm will move from a downwards and backward arc and follow through across the body (POC: NSW, 2003). Attempts at this process will be made with many mistakes occurring (Fitts and Posner, 1967; Ives 2014).

Associative stage: less mistakes when performing the throw will be made, however the performer will still need to consciously think about executing each individual coaching point described above (Fitts and Posner, 1967; Ives 2014). For example, a fielder in cricket would have to consciously stand side on before throwing the ball back.

Autonomous stage: at this stage the cricket player would automatically perform the correct technique of the over arm throw. The performer would not have to consciously think about executing the individual components and performance would be optimised (Fitts and Posner, 1967; Ives 2014).

**1.2.3.4 Schmidt's schema theory (1975)**

Schmidt (1975) used a pre-existing theory created by Adams (1971) and developed it further. Firstly, Schmidt (1975) suggested that people do not develop motor programmes but they develop 'schemas'. A schema is described as a set of generalised rules or generic rules for a set movement pattern. Firstly Schmidt (1975) identified two types of memory: recall memory, involving the choice and initiation of an action; and recognition memory, evaluating an ongoing movement and making the appropriate changes. Schmidt (1975) explains that it is not necessary to have previous experience in the exact initial conditions or response parameters to be able to execute an action or movement skill. If a recall schema has been developed then the CNS can automatically adjust to suit the similar situation. Schmidt (1975) explains further that the development of schemas is controlled by error labelling. When skills are performed, sensory feedback is taken to the CNS, if there is a mismatch between the desired outcome and the actual outcome then an alteration will be made for that schema.

As mentioned, Gallahue and Ozmun (2002) recognised that eight FMS underpin other sporting and physical activities. Applying Schmidt's (1975) theory, when children learn FMS, a schema will be developed, so

when children progress to participate in sports, they can refer to the generalised set of rules the schema holds and transfer them to the sporting situation. For example, in tennis, the schema for the over-arm throw could be adjusted to perform the action of the tennis serve. This theory underpins the evidence detailed throughout this research regarding the importance of learning the eight FMS for successful participation in PA and sport.

## 1.3 Weight status and obesity

Section 1.2 has highlighted that development of FMS is an important prerequisite for PA participation (Okely et al., 2004). Increasing levels of obesity in England are reported to be a consequence of the increasing amount of children not meeting the recommended PA guidelines (Craig et al., 2008). This section of the introduction will provide theory and background as to how and why the nation is becoming more obese and the detrimental effects it can have on health.

A person's mass is the combined sum of everything in the body including bones, fat, muscles and organs (Fink et al., 2009). The two compartmental model categorises these into fat mass and fat free mass (Withers, 1998). Fat mass is defined as the combination of essential fat (fat around the organs) and stores of non-essential fat (adipose tissue) throughout the body (McArdle et al., 2010). Fat free mass consists of muscle, bone, organs and other tissues (Fink et al., 2009). Although fat free mass can increase, (e.g., a gain in muscle mass) this is not often dangerous to health (Smith, 1979). However, when fat mass is increased this can become

detrimental to a person's health (Labarthe, 2011). Once fat mass reaches a level in which it could have a negative impact on a person's health they will be defined as overweight and then obese.

A person will become overweight and obese by an imbalance of energy intake and energy expenditure (WHO, 2000). When energy intake is greater than energy expenditure the extra energy will be stored as excess adipose tissue in the body (WHO, 2000). The latter is known as a positive energy imbalance. Once this excess adipose tissue builds up, it will put the heart, lungs and other vital organs under more stress and become dangerous to that persons health. This increase of adipose tissue will cause the heart to increase its cardiac output to meet the demands of the extra tissue. Furthermore, this increase in adipose tissue is associated with increased deposits of low density lipoproteins (LDL) in arterial walls (Must and Strauss, 1999). This will put the heart under unnecessary strain and increase the likelihood of developing hypertension, which could lead to other cardiovascular disease (Must and Strauss, 1999). If a sufficient amount of daily energy expenditure/PA is accomplished to ensure an equal energy balance, then a healthy body mass is more likely to be maintained.

The most widely used method to identify a person's weight status is to calculate their body mass index (BMI). BMI takes into account the height (cm) and mass (kg) of a person by using the following calculation; BMI = $kg/m^2$. For adults, the cut offs for BMI are displayed in table 1.1. Due to children growing and maturing at different rates, Cole et al., (1990) has produced age and sex reference curves to better identify children who are overweight and obese. Although, using age and sex specific cut offs to

account for maturity rates is useful, still by using age to classify weight status, it assumes that all children will grow at the same rate. However, Cole et al., (1990) still attempts to overcome the issue of 'normal' BMI with children by creating specific BMI cut offs for children based on 1990 reference curve data to predict if they will be overweight/obese when they reach the age of 18. These cut-offs are discussed further in chapter 3.4.

Table 1.1 BMI cut offs for weight status in adults (WHO, 2014).

| Category | Cut off ($kg/m^2$) |
|:---:|:---:|
| Underweight | <18.5 |
| Normal weight | 20-25 |
| Overweight | 25-30 |
| Obese | 30-35 |
| Morbidly obese | >35 |

Obesity has affected aspects of human life and society for over 20,000 years (Williams and Fruhbeck, 2009). According to the Health Survey for England, between 1995 and 2011 the prevalence of obesity has progressively increased in children aged 2-15 years old from 11 to 17% in boys and from 12 to 15% in girls (National Obesity Observatory, 2012). If these trends persist, and numbers continue to rise at a similar rate, by 2050 it can be predicted that 60% of men and 50% of women will be obese (Foresight 2007). Children have a 45% increased chance of being obese in later life if just one parent is obese (Zaninotto et al, 2006). Therefore, interventions for body weight management and education of healthy living for

children are a necessity. Epstein et al., (1987) reported that families following a weight management programme had enabled children with obese parents to return to a healthy weight status; reinforcing the need for education on leading a healthy lifestyle, this is one method that could help to decreasing obesity levels. Furthermore, research has shown that children with obese parents have a larger input into the decision making about healthy choices such as PA participation (Murphy et al., 2012); suggesting the importance of teaching children how to make healthy decisions when it comes to PA participation.

A suggestion as to why there is this trend of increasing weight status is the continued advancement of the technological society (Lakdawalla and Philipson, 2009). Technological advancements are created to enable tasks to be completed quicker and easier, to cope with increasingly busy lifestyles, but in turn this promotes physical inactivity. For example, people will use lifts to the top of buildings instead of using the stairs or writing an email rather than walking to a post box to post a letter, therefore choosing an option that will not expend as much energy in order to save time. However, technology will always be advancing and creating ways to make life easier; therefore the decreased energy expenditure through these advancements in technology needs to be increased somewhere else to prevent the onset of overweight and obesity.

Furthermore, with more parents having to work, there is less time for them to spend in the kitchen cooking from scratch, it is quicker for them to cook ready meals or processed food that is high in saturated fat and salt (Jabs and Devine, 2006). A cross-sectional report on family meal times has

reported that 75% of parents do cook with fresh/raw ingredients in the kitchen, but only two to three times a week. Suggesting that up to five days a week ready meals and processed frozen foods are being consumed (Murphy, 2010). A qualitative study that interviewed parents reported that due to this busier life style, they did not have time to play with their children outside and that as a result television and computer games were reported as common activities (Veitch et al., 2005). Rey-Lopez et al., (2008) conducted a review on sedentary behaviour and obesity in children and adolescents. Fourteen studies that included children under 10 years old reported a significant association between TV viewing and risk of obesity (Rey-Lopez et al., 2008). Children that watch 3-4 hours of TV a day have an increased change of being obese (Gortmaker et al., 1999). By spending more time indoors, children are not getting the opportunity to expend the necessary energy to compensate for the high energy foods they are eating. Therefore, creating a positive energy balance resulting in storage of adipose tissue and body mass gain.

### 1.3.1 Effects of overweight and obesity on health status

There are a range of negative consequences of being overweight or obese including those that directly influence physiological and psychological well-being. Obesity and other cardiovascular disease risk factors such as hypertension and high cholesterol have been tracked from childhood through to adulthood (Gutin et al., 1994; Riddoch and Boreham, 1995). By

maintaining a healthy weight status in childhood it will help decrease the likelihood of developing cardiovascular disease in the future.

Being overweight and obese can be detrimental to a person's physiological health status (Gumbiner, 2001), These physiological disorders can be easily treated with weight loss from PA participation. The physiological conditions as a result of obesity are discussed below. If such physiological conditions can be prevented by treatment or intervention in childhood, children are more likely to progress to a healthy adulthood. A common condition that becomes apparent as a result of obesity is hypertension (Bakris and Baliga, 2012). The excess fatty tissue in obese individuals increases their vascular resistance (due to vasoconstriction) and in turn the heart has to work more (due to an increase in cardiac output) to pump the blood around the body (Bakris and Baliga, 2012). Hypertension then becomes a major risk factor for other physiological conditions, such as strokes (Aiyagari and Gorelick, 2011), myocardial infarctions and aneurysms of the arteries (Edlin et al., 2000). Hypertension is also a risk factor towards atherosclerosis, which is a build-up of fatty deposits in the arteries that supply the heart with oxygenated blood in order for it to work (George and Johnson, 2010). When these fatty deposits build-up it can cause a blockage in the artery resulting in heart failure; this is known as coronary heart disease (George and Johnson, 2010).

A disease that is primarily caused by obesity is diabetes mellitus type II. Insulin is a peptide hormone that is produced in the pancreas to control blood glucose levels (Leong and Wilding, 1999). However, when a person gains 'fat' it is stored as adipocytes. This higher number of adipocytes

physically blocks the insulin receptor cells and inhibits the insulin from reaching the receptors to promote the conversion of blood glucose to glycogen (Peacock, 2000). Therefore, blood glucose remains high, which can result in strokes, heart disease, kidney failure, hypertension, blindness and amputation of limbs (Peacock, 2000). However, if weight is lost and there is a reduction in adipocytes, that will uncover the insulin receptors and allow for promotion of the conversion of blood glucose to glycogen. Thus, diabetes mellitus type II can be reversed when a person loses fat mass (Kopp et al., 2003).

When people are obese they will be more likely to suffer from many combinations of these physiological diseases and be on a high amount of varying medications to control them. If body fat is not lost then the consequences of these conditions is often death (WHO, 2013). However, before death, people will develop these aforementioned diseases as a consequence of being overweight / obese and may be unwell for a long period of time before they die. This causes major strain on NHS resources and this is why the NHS spends £5 billion a year on illnesses caused from being overweight / obese. However, if fat mass is lost then many of these conditions can be reversed and resources can be protected.

Obesity can cause the onset of many psychological disorders and will affect different people in different ways, such as eating disorders, body image problems, self-esteem issues, mood disorders, and social disengagement (Talen and Mann, 2009). These disorders have been linked to body mass gain and the failure of weight loss maintenance (Talan and Mann, 2009). Psychological issues are hard to measure compared to

physiological matters (Garasky et al., 2009) and diagnosis can take longer (Mond et al., 2006), leaving the disorder to grow. Furthermore, people often possess a stigmatising attitude towards people with psychological disorders, thus prolonging the time it takes for people to seek treatment and to be diagnosed (Masuda et al., 2007). When a child is overweight or obese they are 1.5 times more likely to be bullied at school (Griffiths et al., 2005). Being bullied can affect a person's mood, self-esteem, self-efficacy, anxiety and depressive state (Xu et al., 2011). This often results in a reclusive (therefore sedentary) behaviour (Frontear, 2007) and many will turn to food as a comfort. Children who are overweight / obese will not have the self-confidence to participate in PA to expend the extra kilo-calories (energy intake) they are consuming. This results in further weight gain, cascading into a negative downwards spiral. This can affect the mental state of a child, having the potential to result in depression and a lack of self-esteem (Smith, 2009). Research has shown that following a six week PA intervention, BMI and body esteem scores improved (Duncan et al., 2009), highlighting that PA can improve psychological health. The longer it is left untreated the harder it is to recover from. In childhood, the mind is still learning and therefore psychological issues are more easily reversed at this time point (Helwig et al., 2007). Therefore, it is important to target children in early childhood (age 7 years) for prevention and intervention for overweight and obesity.

## 1.4 Physical Activity (PA)

According to the WHO (2013; http://www.who.int/dietphysicalactivity/pa/en/) PA is defined as 'any bodily movement produced by skeletal muscles that require energy expenditure'. There are many different PA guidelines but the one that is used by the department of health (DoH, 2011) is that children complete 60 minutes of moderate-vigorous physical activity (MVPA) per day to maintain a healthy lifestyle. In the UK, 30% of boys and 40% girls do not reach these recommended guidelines (British Heart Foundation, 2009). Physical inactivity is the sole cause of an estimated 3.2 million deaths worldwide, equating to 6% of deaths which could have very easily been prevented (Lee et al., 2012).

Exercise is often confused with the term PA. Exercise is a subgroup of PA which is completed with the aim of improvement or maintenance of one or more components of fitness (National Institute of Health, 2011). Exercise has a purpose, is planned, structured and regular. PA consists of exercise or any other activity that requires a whole bodily movement such as, playing, working, active transportation (walking/cycling), daily tasks (household chores) and physical leisure/recreational activities (Dishman et al., 2013).

According to WHO (2014) a child's PA is made up of play, games, sports, transportation, chores, recreation, PE, or planned exercise, in the context of family, school, and community activities. One of the largest contributors to a child's PA is their active play, which is predominantly made up of time spent outdoors (Brockman et al., 2010). A child's active play is very sporadic and intermittent (Welk et al., 2000), which makes it extremely

hard to record in research. This time spent in play is important not only to make up a child's recommended guideline for PA but also for the related physiological and psychological benefits (Strauss et al., 2001). Not only is time spent in active play important, time spent in structured activities is equally important: Firstly, to ensure that they perform the required amount of MVPA to gain the health enhancing benefits (US DoH, 2008); Secondly, to ensure that they receive coaching on how to develop their FMS and are given opportunities that are intense enough for them to practice, develop and refine them (Haywood and Getchall, 2002).

There are many barriers towards PA such as, socioeconomic status, urbanisation, social differences and environmental differences (Carver et al., 2008), parental influences (Steinsbekk et al., 2011) and psychological barriers (Abbott and Barber, 2011). These are discussed further in section 1.5.3.

Motor development of FMS is thought to influence a child's PA level, which will inform their weight status (Stodden et al., 2008). The following literature review will discuss research that has identified relationships between these three variables (FMS, PA and weight status) and highlight gaps/inconsistencies that will be addressed in this research.

## 1.5 Review of the literature

### 1.5.1 Developmental mechanisms influencing the physical activity trajectories of children

Stodden et al., (2008) proposed a theoretical model that explains the interaction between the development of motor competence (MC), PA participation and weight management (Figure 1.1). Stodden et al., (2008) suggest that MC is the underlying mechanism that will influence PA engagement. However, the model stressed that PA is also mediated by age, perceived motor competence (PMC), health related fitness (HRF) and the risk of obesity (Stodden et al., 2008).

Figure 1.1 Stodden et al's., (2008) conceptual model of developmental mechanisms influencing the physical activity trajectories of children.

During early childhood, the cognitive capability to accurately perceive motor competence is not developed (Harter, 1999) and therefore this model suggests that there would be no relationship between MC and PMC at this stage. When children reach middle to late childhood their cognitive ability is constantly improving and they begin to have the ability to compare themselves to their peers (Harter, 1999), therefore, MC and PMC begin to show a relationship. Children who have a higher PMC due to their higher MC will perceive tasks to be easier and are more likely to engage in them (Goodway and Rudisill, 1997; Weiss and Amorose, 2005). This engagement will allow the child to practice and increase their MC, maintain a healthy

weight status and enter the positive spiral of engagement. However, children who have a lower PMC due to their lower MC will opt out of engagement in PA as they now have an understanding that they are not as good as their peers. Children will not want to display low motor competence in front of their peers which will have a negative influence on motivation (Goodway and Rudisill, 1997; Weiss and Amorose, 2005). This decreased engagement in PA will not give the child the chance to develop their MC resulting in weight gain, leading to the negative spiral of disengagement (Stodden et al., 2008).

In early childhood, the model suggests that there is no relationship between MC, HRF and PA. At this age, these variables will vary a lot between different children (Harter, 1999, Stodden et al., 2008). However, when children reach middle to late childhood, children with a higher MC will demonstrate an increased health related fitness compared to a child with a lower MC (Enoka, 2002). Children who hold a higher HRF will be able to participate in PA for longer and at an increased intensity compared to a child with a lower HRF. This allows them more time to develop their MC and again entering the positive spiral of engagement (Tammelin et al., 2003; Stodden et al., 2008). The children who have a decreased HRF will not be able to participate in PA for as long. Children are not given the opportunity to develop their MC due to the reduced time in PA and as a result display the negative spiral of disengagement. The relationship between physical inactivity and unhealthy weight gain has been widely established (Fogelholm and Kukkonen-Harjula, 2000; Donnelly et al., 2009). However, the underlying mechanisms of this undesirable relationship are yet to be identified. Stodden et al's (2008) model suggests that when a child is overweight or obese and

they attempt to partake in PA, they are likely to be unsuccessful due to their lower MC for that task. This will decrease motivation and drop out is likely to occur, resulting in the negative spiral of disengagement.

## 1.5.2 FMS and PA

On the principle of Stodden et al's (2008) conceptual model there is an association between FMS competency and PA level. Research has investigated the link between these two variables and has generated equivocal evidence. Such evidence will be critically evaluated throughout this section.

Firstly many cross sectional studies have been completed to report relationships between FMS and PA. However, it is important to remember that when a study is cross-sectional it cannot determine causality, for example, it is not clear if FMS influences PA or if PA influences FMS. Lubans et al., (2010) conducted a systematic review on 'FMS in children and adolescents'. The review consisted of 21 articles that coincided with very strict inclusion criteria. Lubans et al., (2010) reported that in 11 of the studies FMS was associated with at least one of the following: organised PA; non-organised PA; pedometer step counts (Okely et al., 2001; Graf et al., 2004; Fisher et al., 2005; Hamstra-Wright et al., 2006; Castelli and Valley , 2007; Barnett et al., 2008; Erwin and Costelli, 2008;  Hume et al., 2008; Williams et al., 2008; Cliff et al., 2009; D'Hondt et al., 2009). Of these 11 studies that were reviewed, ten of them had a cross sectional design, therefore just

reporting associations between FMS and PA and cannot suggest any temporal relationship.

Okley et al., (2001) conducted a study on 90 pupils between grade eight and ten (13-16 years old), assessing their self-reported time spent in organised and non-organised PA and six process oriented FMS. The study reported that 3% of organised PA can be predicted from FMS levels ($r^2$=0.03). Although a significant amount, 3% is very low and leaves 97% of the variance in PA unexplained. By using a self-reported measure of PA the adolescents are subject to demand characteristics and giving socially desirable answers (Burrows et al., 2010; Lee et al., 2010). Therefore, such self-report increases the likelihood of over estimating the amount of PA participants undertakes. As these pupils are aged between 13 and 16 years old they will be cognitively developed to understand whether they should be partaking in more PA then they currently are. Therefore, pupils who lack competency in FMS are likely to overestimate their PA level. This may at least partly explain why such a weak correlation is reported between organised PA and FMS. There was no significant correlation between FMS and non- organised PA, suggesting that FMS is only associated with organised PA. However, non-organised PA is significantly less likely to be observed in adolescents when compared to organised PA (Santos et al., 2009), suggesting why there is no relationship between FMS and non-organised PA.

Similar to Okley et al., (2001), Hamstra-Wright et al., (2006) conducted a study which collected data on organised and non-organised PA using a self-report method. However, the sample population was nine year

old children. Okley et al., (2001) had a small sample size (90) compared to the other studies that will be discussed in this section which decreases the likelihood that the results are truly representative of the wider population. Hamstra-Wright et al., (2006) used an even smaller sample size of 36 children. Thus, results from these two studies must be interpreted with caution. The limitations with self-report PA level are described above; however, if children are under 12 years old, it is advised that parents fill out the questionnaire regarding their child's PA level (Burrows et al., 2010). However, parents are also just as likely to be subject to demand characteristics and overestimate their child's PA level (Burrow et al., 2010; Lee et al., 2010). Unlike all the other research that uses regression analysis to predict variance of PA (independent variable) from FMS level (dependent variable), Hamstra-Wright et al., (2006) used locomotor skills as the independent variable and type of sport (organised/non-organised) as the dependent variable (Okely et al., 2001; for McKenzie et al., 2002; Barnett et al., 2009; Cliff et al., 2009). However, it was reported that 29% ($r^2$=0.29) of the variance in locomotor skills was accounted for by organised sport. This is a much higher percentage of variance produced than the other studies that use the predictor variable as the FMS competency level (3% for Okely et al., 2001; 10.4% for McKenzie et al., 2002; 3.6% for Barnett et al., 2009; 19.2% for Cliff et al., 2009). From reviewing these differences it suggests that maybe it is PA that predicts more of the variance in FMS compared to the amount of variance that FMS predicts in PA. However, this study is cross sectional and therefore cannot determine causality.

Fisher et al., (2005) conducted cross sectional research on 394 preschool children (four years old). PA was collected via accelerometers and children had to complete 15 movement tasks. Significant correlations were reported between the children's movement score and PA (p=0.039); movement score and MVPA (p<0.001). However, the r values for these correlations indicate small relationships (r=0.1 and 0.18 respectively). Other research has stated that the relationship between FMS and other variables are not established until the age of school entry (Hardy et al., 2010; Kelly et al., 2006), suggesting that these correlations will most likely get stronger. This was the case for D'Hondt et al., (2009) whose study was on older children (5-10 years) than used by Fisher et al., (2005). PA was collected using accelerometers and eight FMS were assessed. Larger correlations were reported between these variables (r=0.2-0.21). Furthermore, Hume et al., (2008) conducted research on even older children, 9-12 year olds. Accelerometer data was collected along with the assessment of six FMS (kick, throw, strike, run, dodge and jump). Larger correlations again were reported between FMS and PA (r=0.21-0.29) compared to Fisher et al., (2005). Although larger correlations were highlighted, the difference was small and the effect of the correlation was still small. However, if correlations continued to become stronger as children age, by the time they are adults the effect sizes of the correlations could be much stronger.

Williams et al., (2008) reported data on PA and FMS levels of three (pre-school) and four year olds (first year of school). Significant correlations were only highlighted for the four year old children and not the three year old children. Therefore, further support that a significant association between

FMS and PA are not present until children reach school. Furthermore, it was reported that children who had higher levels of FMS spent 2% more time in MVPA and 1.2% more time in VPA per day when compared to children with lower FMS score. Although this difference may seem very small, it translates to 12 more minutes spent in MVPA with ≥2 minutes of that time in VPA per day. If this is translated into a five day week then total time spent in PA could be around 1.2 hours more per week for children with higher FMS competency.

The research reviewed above largely indicates that there is a relationship between FMS and PA, the extent to which FMS and PA are linked has not yet been fully established. Fisher et al., (2005) highlights importantly, that FMS is not an exclusive predictor of sustained PA but can influence it. Vandorpe et al., (2011) identified that participation in PA and partial participation in PA (this is if a participant had started or quitted a sports club in the three years of the study) will significantly increase FMS mastery compared to sedentary behaviours. However, there was no significant interaction between time and sport participation. Therefore, suggesting that PA increases FMS mastery but not by the rate at which children mature. Vandorpe et al., (2011) divided their sample by PA level ('no participation' where children were not activity involved in a sports club in the three years of study; 'partial participation' - as defined above and 'consistent participation' – children who were engaged in sports clubs throughout the three years of study). Whereas, Baskit et al., (2011) recruited their sample groups on type of PA; individual sports, team sports and racket sports. Baskit

et al., (2011) elucidates that there was no significant difference between the three sports groups and concludes that type of PA is irrelevant in enhancing FMS, but PA in general is essential. However, there was no control group to compare the FMS scores with, thus limiting the conclusions that can be drawn from the results. If a control group was used a specific PA may have been highlighted that could maximise FMS mastery compared to sedentary behaviour.

The most reliable method to identify the relationship between FMS mastery at childhood and a sustained PA level in adolescence would be to conduct a longitudinal study on the same set of participants (Summerbell et al., 2005). Lubans et al., (2010) conducted a systematic review on 'FMS in children and Adolescents'. Out of the 21 studies, only four were longitudinal (6-7 years long). Furthermore, three out of the four studies were created from the same study conducted by Barnett et al., (2008), therefore narrowing it to just two longitudinal studies in the review. Barnett et al., (2008) reported an association between childhood FMS mastery and PA levels in adolescents. In contrast to this, the other longitudinal study conducted by McKenzie et al., (2002) found that FMS mastery at ages 4-6 years did not forecast the PA levels of some of the children at age 12 years. Lubans et al., (2010) suggests this lack of relationship between FMS and PA is because only three FMS were tested and a 0-2 scale was used to identify the mastery level of the FMS. However, if this is the case then it is surprising that the authors of this review (Lubans et al., 2010) did not change their inclusion criteria to include studies that assess more than three FMS and use a larger and more sensitive assessment scale. The three FMS that Mckenzie et al., (2002)

assessed were, catching, jumping and balancing. It could be that these three FMS are not influential in the maintenance of a healthy PA level and that it could be other FMS that were not assessed that are important in the prediction of future PA levels. Furthermore, McKenzie et al., (2002) targeted preschool children; at this age children have not had the experience of PE nor had the opportunity to fully develop their FMS. This suggests why there was no relationship shown between FMS mastery level at preschool age and PA level at age 12 years.

To gain and maintain FMS mastery, Haywood and Getchall (2002) emphasize that FMS needs to be taught and practiced as they do not develop naturally as a child matures; this account is supported by: Goodway and Branta (2003); Valentini and Rudisull (2004) and Robinson and Goodway (2009). Vandaele et al., (2011) suggest that FMS should be learned, developed and mastered between the ages of four and six years old. Thus, proposing that PE lessons are the superior setting to develop FMS (Sallis et al., 1997). Teachers can improve FMS through support and mentorship within an educational environment (Mitchell et al., 2011). Branta et al., (1984) identifies that FMS are developed sequentially and thus highlighting that 'free play' will not contribute to FMS development and that more structured lessons are vital (Gagan and Getchall, 2006). As stated earlier, it has been suggested that FMS are developed in the first four to six years of a child's life. However, the same study identifies that a child learns its first FMS skill of balance when he/she learns to sit up and then stand (Vandaele et al., 2011). Once standing on two feet, basic balance has been mastered. The child will then progress to walking which will involve shifting of

the body mass to allow for the forward swing of the leg, therefore mastering the key mechanisms to balance on one leg, which is assessed later in this thesis. Once this has been mastered children can then progress on to the more complex skills that require further mastery.

Throughout the literature, there has been contrasting conclusions about PA and FMS mastery level. Some research suggests that FMS mastery will influence PA participation whereas other research suggests that an increase in PA participation will increase FMS mastery (Graff et al., 2004; Hume et al., 2008). Stodden et al's (2008) model suggests that it is the MC that is the primary mechanism that will affect PA levels which causes a chain of events, to promote a change in weight status. Nevertheless, it's essential that there is a wide range of physical activities available to cover all the FMS for development (Haga et al., 2008; Vandaele et al., 2011). This is not only for physiological health, but to give children the skill set to partake in an activity of their choice. However, actual participation in physical activities as well as the opportunities of the wide range of activities is decreasing throughout children in developed nations such as the UK (Kahl et al., 2002; Anderson et al., 2006). Although children may manage to gain the skills required to participate in activities, engagement in the activity alone is not enough, PA needs to be at a more structured for the mastery and maintenance of the FMS (Vandaele et al., 2011). Vandaele et al., (2011) reported that relationships between movement skills and MVPA are predominantly stronger, compared to low intensity PA. Suggesting, that when children engage in MVPA the development of FMS is more effective. When learning new movement patterns, the problem of 'degrees of freedom' can become an

issue (Bernstein, 1967). Degrees of freedom is explained as; more than one motor program that can be simulated to lead to the same trajectory (Berthouze and Lingarella 2004). Therefore, the brain needs to control all degrees of freedom at every point during the performance of a movement pattern (Kelso, 1982). Newell (1991) reported that the degrees of freedom must be converted to a controllable system. It has been suggested that kinematic links that participate in a movement are subdivided into a smaller number of connected groups or linkages (Kelso, 1982). To promote these linkages, practice and repetition of the movement patterns need to occur until the movement is automated and the degrees of freedom is reduced (Newell, 1991). Therefore, if children engage in more intense PA then it offers greater opportunity for the repetition of the FMS in more ecologically valid situations, to create these linkages.

To be able to participate in more structured physical activities this often means going to an afterschool or an external sports club. However, there are potential barriers that could stop children going to afterschool or external sports clubs. For example these barriers could be financial (coaching fees, the expense of equipment and kit, club membership fees), transportation (transport to training and transport to games/matches) and psychological barriers (self-confidence, self-efficacy and perceived competence) (Eime et al., 2008; Ziviani et al., 2009).

### 1.5.3 Barriers to PA and FMS competency

### 1.5.3.1Socio Economic Status (SES) and Urbanisation

An important factor that will affect a child's PA level is the environment that they live in. Singh and Kogan, (2008) have reported that children from a lower SES have an increased chance of having a higher BMI and being overweight or obese. Research suggests that children with an increased weight status lack mastery of FMS (O'Beirne et al., 1994; Hammond, 1995; Lopes et al., 2011; Visser et al., 1998; Wasmund-Bodenstedt, 1988; Cairney et al., 2005). However, Hardy et al., (2010) showed no significant difference in FMS mastery in preschool children aged two –six years from different SES groups. In contrast to this, Hardy et al., (2010), Kelly et al., (2006) suggests that SES will show its influence on obesity and FMS at the age of school entry.  Once reaching school age, SES has such an influence on PA participation due to variation in financial ability to pay for some school clubs, external sports clubs, kit, equipment, transportation and membership fees (Giles-Corti and Donovon, 2002; Leboeuf, 2013).

The environment around the child's home can also affect a child's PA level (Sallis et al., 2000) and thus FMS level. If families live in an area of deprivation, parents are less likely to allow their children to play outside due to safety concerns (Eyre et al., 2013). When outdoors children spend more of their time in MVPA (22.6%) compared to when they spend time indoors (4.4%) (Cooper et al., 2010). Time spent in MVPA has been linked to an increase in FMS development (Vandaele et al., 2011). Rural and urban areas can also affect PA levels of children (Eyre et al., 2013). Loucaides et al.,

(2004) reported that children from rural areas have more space to play outside and parents deem the space as a safe environment. It was also reported that children from more urban areas are transported to places where they can be physically active (Loucaides et al., 2004). It can be said that, children in rural areas will have more opportunity to be physically active as they do not need to have parents available to transport them to PA opportunities. With parents becoming busier it will be much harder for them to transport their children to enable physical activities (Veitch et al., 2005). As stated, Vandaele et al., (2011) suggest that FMS will not develop purely from free play and that something more intense is needed. Therefore, SES should not be associated with FMS level. However, Murray (2006) reported that children from a higher SES may have better accessibility to sports clubs, where FMS can be developed and further practiced during play. Hardy et al., (2012) reported that there was no difference in rural/urbanisation in FMS competency but there was in SES, concluding that the important factor is the accessibility to clubs and organised PA sessions where FMS can be taught, learnt and practiced.

### 1.5.3.2 Parental Influences on PA and FMS

Bois et al., (2005) reported that a child's perception of self-competence in relation to PA is directly influenced by their parent's perception of their child's ability. Parents of overweight/obese children perceive them to be less physically competent compared to parents of 'normal' weight children (Jones et al., 2010). Although these perceptions are

likely to be correct, parents must verbalise positive encouragement about the child's competence to persuade them to increase participation levels of PA (Jones et al., 2010). Furthermore, Graf et al., (2008) conducted a study which included a four year intervention of 30 minute health lessons on: biological background, nutrition and self-management; five minute active breaks were giving during lessons and PA options (information on the PA options was not reported) were available in break times. Over the four years, 23.2% of the overweight and obese students from the intervention schools reached a normal weight with 19% of overweight and obese students from the control schools reaching normal weight. There was no significant relationship between overweight/obesity and FMS mastery level, emphasizing that engagement in PA alone is not enough to develop mastery of FMS and that parents need to show support and understand that more needs to be done in PE lessons and outside of the school setting.

### 1.5.3.3 Psychological Barriers to PA and FMS

Children are often excluded from playground games due to their lack of skill (Ignico, 1990). If children already have a lack of skill and are further left out of playground games then, potentially children may not have the confidence to join an afterschool/sport clubs where sports specific FMS would be taught by a coach. Children will detach themselves from their peers to avoid any unwanted attention (Frontear, 2007). As previously stated this minimises any chance of friendship or identity to a social group and results in a secluded life style with the individual judging themselves as not worthy.

Due to research identifying the importance of FMS mastery influencing PA participation (Okely et al., 2004; Barnett et al., 2008), it can be speculated that if children can master the FMS then they are likely to be included in games in the playground due to successful execution of the skills (Stodden et al., 2008); Thus, resulting in an increase in PA level and an increased likelihood that they will maintain a healthy weight status.

How children perceive their own ability can also affect a child's motivation to partake in PA. These issues are discussed further in section 1.5.6.

## 1.5.4 FMS and Body composition

Previous research has highlighted that FMS is negatively affected by weight status (Wasmund-Bodenstedt, 1988; O'Beirne et al., 1994; Hammond, 1995; Visser et al., 1998; Cairney et al., 2005; Lopes et al., 2011). Out of the 21 studies cited in the Lubans et al., (2010) systematic review, nine of them used weight status as a variable to compare FMS mastery. Six of the nine studies highlighted a significant inverse relationship between weight status and FMS mastery (McKenzie et al., 2002; Graf et al., 2004; Okley et al., 2004; Southall et al., 2004; Erwin and Castelli, 2008; Cliff et al., 2009; D'Hondt et al., 2009). Okley et al., (2001) established consistent data with that above highlighting that overweight and obese children score lower in the locomotor skills when tested (run, gallop, skip and hop). Okley et al., (2001) suggests this is because they have an increased body mass to move over a distance, therefore making it harder for them to execute the skill

according to the criteria that it is being assessed on. D'Hondt et al., (2009) supports this and suggests that balance is also affected by increased body mass, as it affects one's posture and stability, making it harder to maintain balance for the required time. Furthermore, the duration of the balance could be reduced due to pain caused to the knee/hip/ankle by greater body mass increasing pressure on the joint.

As previously stated, Mckenzie et al's (2002) study did not show a significant relationship between childhood FMS mastery and adolescent PA levels. However, it did show an inverse relationship between FMS and weight status. Conversely, other research has shown that there is a direct link between healthy body weight, PA participation and FMS competency; FMS will influence PA of which the energy expenditure exerted during the PA will balance out the energy intake in the diet and therefore a healthy weight will be maintained (Wasmund-Bodenstedt, 1988; O'Beirne et al., 1994; Hammond, 1995; Visser et al., 1998; Cairney et al., 2005; Lopes et al., 2011). If weight status in children reaches a healthy level, it will aid the development of FMS as children will be able to move more easily (Okley et al., 2001) and have more flexibility around the joints to perform the skills correctly (Lamari et al., 2005). As a result of this, participation levels in physical activity will increase. Or if FMS can be mastered in early life then children will partake in more PA (Barnett et al., 2008) and will not become overweight in the first instance. Consequently by developing FMS at an early age it can be used as a preventative measure for physical inactivity and obesity.

**1.5.6 FMS and Self perception**

Stodden et al's (2008) model suggests that a child's PA level will be made up of a combination of AMC and PMC. However, this is once a child has developed the cognitive ability to be able to compare their own skill level to their peers. Research predominantly supports Stodden et al's (2008) theory that PA participation will be affected by a child's physical self-perception (Carrol and Loumidis, 2001; Robinson, 2011; Barnett et al., 2008). Hardy et al., (2012) highlighted the importance of how an increased perceived competence can lead to a positive chain of events; increased FMS competency, increase in PA participation and maintenance of a healthy weight status.

Robinson et al., (2011) conducted a study to identify the changes in object control mastery and self-perception scores over nine weeks. The intervention consisted of 30-min object control skill intervention two days per week for nine weeks. Over the nine week intervention there was a significant increase in object control mastery and self-perception scores. However, the authors did not report if there was a correlation between these two variables. Furthermore, a control group was not used to identify if this change in scores for the two variables was down to physical or cognitive maturation of the child or down to the intervention. In contrast to this, Breslin et al., (2012) did use a control school to understand why differences may occur. Breslin et al., (2012) had two schools; the first school involved training teachers to teach FMS whilst the second school received no formal training. However, Breslin et al., (2012) gave no information about how many FMS session's children

had or how long it was between the measurements. When children were assessed, there was no difference in FMS competency between the two schools. Authors assign this to the fact that although teachers had been trained they had not had long enough to teach the children to display a significant improvement. The length of time between the two measurements was not reported in the paper, causing this conclusion made by Breslin et al., (2012) to become redundant as other research cannot learn from this. Nevertheless, there was a significant difference for self-perception scores, with the children from the intervention school demonstrating a higher self-perception score. Thus, highlighting the importance for teachers to understand how to teach FMS and how this can positively affect a child's physical self-perception to positively influence PA (Carrol and Loumidis, 2001; Robinson, 2011; Barnett et al., 2008). For example, if children perceive themselves to have a higher motor competence then they will perceive themselves to be more successful in PA situations and maybe more likely to initially partake in PA opportunities (Stodden et al., 2008). In addition, Breslin et al., (2012) reported that there was no significant relationship between AMC and PMC; this does not support prior research that suggests the opposite (Stodden et al., 2008; Robinson et al., 2011). Although Breslin et al's (2012) findings are consistent with prior literature it is still interesting that Barnett et al., (2008) reported that children with higher PMC will deem themselves more able to join in activities and therefore have a higher PA level. When children become older than 7 or 8 years (age of the children in Breslins et al's study) this is when the relationship between AMC and PMC

will become apparent as the children will have greater cognitive development (Stodden et al., 2008).

Furthermore, Barnett et al., (2008) concluded that children who have a high motor proficiency will have a higher AMC and PMC when they reach adolescence. This would seem to be consistent with other research that has suggested that there is a relationship between PMC and AMC (Jones et al., 2010). However, the PMC was only measured in the follow up data when the participants were adolescents and only a third of the original sample participated. Results did show that in adolescents PMC was a mediator for PA participation (Barnett et al., 2008). Therefore, authors were unable to conclude if PMC plays an important role in childhood AMC and PA engagement.

Poulsen et al., (2011) identified that children who are classed as overweight/obese will have a significantly lower self-perception score, consistent with other research (Sung et al., 2005; Jones et al., 2010). There was no significant relationship between BMI and perceived competence. Authors suggest that lower PMC levels could be a consequence of personal and environmental factor such as SES. Jones et al., (2010) supports this with reports that parents of overweight/obese children have lower PMC of their children which was mirrored by the children (although this matched with their actual competence). Jones et al., (2010) explains that children are directly influenced by their parents and that if parents verbalise their belief in high competency levels children's perceptions may change and children will be more likely to engage in PA (Carrol and Loumidis, 2001; Barnett et al., 2008; Robinson, 2011;).

Research has identified that it is important that children have high self-perceptions for PA participation; however it needs to be identified if this can be changed through an intervention as a consequence of increasing FMS mastery.

### 1.5.5 FMS and Gender

At the primary school age of 4-11 years old children are pre-pubertal and should not be biologically different and so no gender difference in FMS mastery should be present. Therefore, gender differences between the FMS are likely to be due to environmental factors such as the influences of parents, peers, teachers and media on the choice of activities. There is contradictory evidence between FMS mastery and gender. Ziviani et al., (2009) and Hardy et al., (2010) report that boys and girls excel in different skills. Vandaele et al., (2011) investigated 18 different FMS and assessed gender as one of the variables. It was reported that gender had no effect on the mastery level of the 18 FMS they assessed. This is inconsistent with other research which has highlighted that boys will outperform girls in the object control skills and that girls will outperform boys in balance (Ziviani et al., 2009; Hardy et al., 2010). Children are drawn to stereotyped activities, for example, girls favour activities such as dance and gymnastics, enhancing balance and galloping, and boys favour ball and chasing games, enhancing their catch, throw and running (Pellegrini et al., 2004).

Two intervention studies looking at increasing PA levels and FMS mastery in children found positive results (Graf et al., 2008; Mitchell et al.,

2011). Graf et al., (2008) conducted a four year intervention which included training the teachers and providing extra PA opportunities for the children. Mitchell et al., (2011) conducted a six week intervention which included prior training of how to teach FMS to the class teacher. Despite this, neither intervention recorded the gender of the participants. Mitchell et al., (2011) reported that kicking, catching and striking skills displayed the biggest improvement in 5-12 year old children. These are all object control skills and as stated, boys are naturally better at performing these skills (Ziviani et al., 2009; Hardy et al., 2010). Graf et al., (2008) reported a significant increase in balancing backwards and lateral jumping. These skills are commonly found to be performed better by girls (Ziviani et al., 2009; Hardy et al., 2010). By not splitting the results by gender groups it cannot be concluded whether it was the boys who made the most improvement due to a lower baseline level for these skills (Ziviani et al., 2009; Hardy et al., 2010). Bastik et al., (2011) conducted a study where they compared the FMS competency of three sport groups (individual, racket and team sports) in children aged 10 years old. Again gender was not recorded and unlike school, it cannot be presumed an approximate even split between boys and girls would be apparent. If gender was recorded, an activity that enhanced FMS more than another activity may have been highlighted to a specific gender and could be used for future interventions.

**1.5.7 FMS Interventions**

Logan et al., (2011) conducted a Meta-analysis on 11 intervention studies that focused on increasing children's proficiency in FMS. Each study used a different intervention but all resulted in an increase of skill level. However, eight out of the 11 studies used children that were at risk of developmental delay or had low autonomy, therefore having room for improvement compared to typically developing children. Control groups were described as free play. Five studies used control groups and not one control group showed a significant development of skill proficiency, therefore re-emphasising the fact that FMS needs to be taught, learned and developed and will not naturally advance in free play.

Interventions varied from 480 minutes to 1350 minutes over 6 – 15 weeks. However, there were no differences between FMS proficiency and length of an intervention. Logan et al., (2011) suggests that children will plateau once the skill is mastered. An additional opinion is that interventions can be repetitive, causing boredom and disengagement from the project (Graf et al., 2008). These findings suggest that future interventions need to be exciting and varied enough to keep the children engaged and motivated for the duration of the intervention.

Out of the remaining three studies from Logan et al's (2011) review, the samples used were overweight and obese, children with disabilities and typically developing children. Cliff et al., (2007) used overweight and obese children as their sample with no control group. A nine month follow up was conducted after the 10 week intervention had finished. The intervention focused on providing a range of physical activities to develop six locomotor and six object control skills. Home challenges were also set to encourage

extra practice in the home setting. Overall, FMS significantly improved and stayed significantly higher in the follow up test. However, PA levels decreased from pre to post-test and then further decreased in the follow up. An explanation for this could be that each two hour session a week did not comprise of enough PA and the instruction time may have been long, thus hindering the PA levels of the children during that two hour session. Instruction time was not reported so this conclusion cannot be made. Although, PA decreased, mastery in FMS did increase and this is more important to influence future PA levels (Barnett et al., 2008). So if PA during a PE lesson does have to be decreased to master FMS then it could still have more long term positive benefits on PA. An additional explanation to why a decrease was shown for PA could be due to an initial ceiling effect (for example, children were excited to use this novel piece of equipment so were more physically active compared to normal) when children had to wear the accelerometers. This is supported by the fact that children actually displayed higher levels of moderate to vigorous PA (MVPA) (+20min/day MVPA) compared to a representative sample of similar ages measured using accelerometry (Trost et al., 2001). A potential limitation to using a sample of using overweight and obese children is that they tend to be inactive in the first instance (Page et al., 2005) and when they participate in a PA intervention; their PA will increase compared to normal, increasing the likelihood that they will have an equal or negative energy balance. However, this effect would depend on many individual characteristics and the intensity of the PA intervention. Although there was no significant change in BMI for the overweight and obese children in Cliff et al's (2007) study. However,

there was a decrease in PA over the intervention so a reduction in BMI would not be expected. Conversely, interventions that have increased PA levels in overweight/obese children have found BMI is reduced by a third (Sigmund et al., 2012).

Valantini and Rudisill (2004) also conducted a six month follow up and reported that the effects from the intervention are still present. This intervention lasted for 12 weeks and consisted of implementing two types of motivational climates (high and low) on two separate groups when teaching FMS. Children in both conditions improved in FMS mastery post intervention, it was found that the children in the high motivational climate significantly improved, and this improvement was still present six months later. The validity of all the other interventions would be largely increased if follow up assessments were conducted to identify the long term effects of the interventions on the FMS. It is highly recommended to conduct follow up data (Logan et al., 2011), interventions are not implemented to have a single 'one off' effect but to help make lifestyle changes on a permanent basis.

Each intervention from Logan et al's (2011) review was comprised of sessions focusing on developing FMS. However, the instruction time or type and PA time in each session was not recorded. Van Beurden et al., (2003) conducted an intervention which consisted of supporting teachers, implementing a buddy programme, creating a supportive environment, healthy policies, website, project teams and strategies to develop FMS. They concluded that time spent on instructions is important to record as well as the actual content of each session. Van Beurdon et al., (2003) found that just recording 'skill', 'fitness' or 'game' for each session did not give enough detail

on whether PA levels were kept high enough whilst implementing the intervention. Therefore, an intervention needs to provide sessions that develop FMS whilst keeping PA high. It is consistent between research studies that boys and girls will excel in different specific FMS and that boys tend to be more physically active. However, Van Beurden et al., (2003) reported that boys, when compared to girls, were more active during the intervention. This suggests that interventions may have different effects on boys and girls.

Deri and Patcha (2007) conducted an intervention which investigated the effects of two different teaching styles; command and guided discovery. The command style included the teacher giving a demonstration with coaching points and providing feedback. The guided discovery approach involved no demonstration, but the teacher guided the children to the correct way of performing the skill, allowing the children to experiment. Both groups doubled their FMS mastery level from pre to post-test according to the grading system used (TGMD). However, the guided discovery group did not show a significant decrease in FMS between the post and retention test suggesting that it has better long term effects on FMS retention. Although this decrease in FMS in the guided discovery group was not significant it was still present, thus suggesting an additional follow up measure would be useful to identify if FMS mastery plateaus at a higher level compared to the pre-test. This study did not use a control group and therefore cannot determine if the improvement in FMS was purely down to the intervention or down to natural development in the children. Derri and Patcha (2007)

propose that further research should look at the transfer of these teaching styles to the real (sporadic) play that children demonstrate.

Predominantly, the research in this area consists of interventions ranging from 6-12 weeks (Logan et al., 2011). In theory, the duration of the intervention does not matter, as long as there is a positive effect on FMS and the aim of the intervention is achieved. However, literature has failed to quantify the time needed to be spent on each skill to result in mastery. Furthermore, duration isn't necessarily the most important part of an intervention as the content must be developed to meet the research aim and to have lasting effects.   In contrast to this, Graf et al., (2008) conducted a four year intervention which comprised of one health education lesson a week, a five minute PA break once a morning, PA options provided in break and lunch times and teachers were trained to teach FMS. There were 12 intervention schools and five control schools. Results showed no improvement in endurance (six minute run) in the experimental group compared with the control group, no effect on the incidence of overweight and obese status and only two FMS (lateral jumping and balancing backwards) showed a significant improvement. Although two FMS increased, only four skills were assessed; lateral jumping, balancing backwards, one legged obstacle jumping and sideways movement. Furthermore, these four skills do not replicate the full set of skills needed to be able to partake in all sporting activities. Because, the children had not learnt the full set of skills to partake in a range of activities, thus not allowing them to enhance their HRF, there was no improvement in endurance performance between the intervention and control group. This indicates that interventions need to be

more intense for a more positive effect on weight status, because, by simply providing PA opportunities it does not ensure that children will engage themselves to expend the energy needed to maintain a healthy weight status (Graf et al., 2008). Graff et al., (2008) did report that the implementation of the intervention decreased over the four years and teachers did not deliver it correctly thereby advocating that when interventions are implemented by teachers they need to be more sustainable.

Mitchell et al., (2011) conducted a six week intervention in 11 schools. This involved identifying the weakest FMS in the pre-test and getting the teachers to focus on them in PE and fitness classes. Children also set their own goals for the six week programme. This intervention was successful and all FMS increased. Results highlighted that those children aged five-six years had a larger increase in FMS proficiency compared to the older children. Suggesting that this could be the optimum age for interventions to be implemented. Results from this study also indicated that out of 900 teachers only 11 of them had PE degrees and only 74 had training in PE. The fact that so many primary school teachers are not trained in PE offers an explanation as to why FMS competency is consistently low in primary school settings. A limitation of this study is that no individual characteristics were recorded so potential effects of age, gender and BMI on FMS cannot be identified. As mentioned, this study only concentrated on the FMS that needed improvement. It can be argued that by only focussing on weaker skills is why significant results are shown as there was more scope for improvement. However, by only focusing on the skills that need improvement it allows the children more time developing these weaker skills, rather than focus on all

the skills and spending time on some that do not need it. Jones et al., (2011) conducted a 20 week intervention programme on preschool children that consisted of structured activities (a 20 minute session, three times a week), unstructured activities (to practice the skill they had been taught in the structured session) and staff training (four x 30 minute workshop, including theory and practical). The control group took part in free play. The intervention group significantly improved in overall FMS proficiency compared to the control group. Again no follow up was conducted after this intervention and therefore it is not possible to identify any long term effects.

It has been suggested that preschool settings are favourable for PA interventions because children are young, still learning and bad habits can be prevented (Duncan et al., 2007). However, not all children attend preschool and if an intervention was implemented at this stage then those children would have more of a chance to increase their FMS capability for when they enter primary school. These advanced children would then possess a higher skill level and the other children would be more likely to be left out of games due to their lack of skill (Ignico, 1990). Therefore, it could be suggested that interventions should wait until primary school age when children are all present and can progress at the same time. Furthermore, by implementing interventions in primary school, all children will be targeted regardless of their prior experience before school and all children can benefit.

Hardy et al., (2010) conducted an intervention on preschool children, that included 15 preschools as part of the intervention  and 14 control preschools, with a total of 263 (83% follow up) and 167 (84% follow up)

children, respectively. The intervention was called the 'move and munch' and focused on five main aims: i) choosing water over sweet drinks ii) eating less snacks and choose healthier options iii) increasing fruit and vegetable intake iv) participating in one or more hour of PA per day v) turning off TV or computer and becoming more active. Overall, results indicated that FMS significantly increased in the intervention schools and sweetened drinks in lunch boxes were reduced. However, Hardy et al., (2010) explains that the implementation period of five months was not long enough to change the habit of the children and to notice the effects. This intervention was classed as low intensity which did prove to be adequate to increase FMS.

## 1.5.8 Objective and subjective measurements of FMS

There are two ways in which FMS can be measured, objectively and subjectively. The subjective measurement is the assessments of the technique of the skill, whereas the objective measure is the quantitative outcome once the skill has been performed, for example, speed or distance. Predominantly, research has focussed on the subjective measure when assessing FMS (Okley et al., 2001; Hamstra-Wright et al., 2006; Barnett et al., 2009; Cliff et al., 2009; Fisher et al., 2005; Hardy et al., 2010; D'Hondt et al., 2009; Williams et al., 2008). These aforementioned studies have all reported significant relationship between FMS, PA and weight status. Although less, other research has measured the objective assessment of the FMS and also found significant relationships between FMS, PA and weight status (Mckenzie et al., 2002; Hands 2008). The reason why predominantly

most of the research measures the technique of the skill is because it is important that the developmental stage of the child is identified (Haywood et al., 2012). For participation in sport or PA, children's success will often be down to the objective outcome of a skill. For example, how fast they can run, how far they can throw, how high they can jump, if they can catch a ball. However the technique of the skill will underpin the objective measurement. However, literature has not assessed if the technique of the skill correlates with the objective outcome. Therefore this will be assessed in the research.

### 1.5.9 Summary

It is clear that FMS is related to children's habitual PA level and weight status. Overall, studies indicate that FMS competency is an important prerequisite to instil the key competencies needed to lead a physically active lifestyle whilst maintaining a healthy weight status. However, the research that suggests this, has predominantly been conducted in Australian children (Okely et al., 2001; Beurden et al., 2003; Okely et al., 2004; Cliff et al., 2007; Barnett et al., 2008; 2009; Cliff et al., 2009). The results reported in Australia cannot be generalised to British children due to cultural, environmental and most importantly curriculum differences (ACARA, 2005). In the UK, PE is often a significant contributor to a child's PA level (Biddle et al., 1998; Fairclough and Stratton, 2005), therefore it is important to understand information on children's FMS level and how it is related to PA and weight status in children.

Much of the literature discussed in this chapter is incomparable due to factors such as: a lack of longitudinal data to track children's FMS level; BMI being used to assess body composition; samples being categorised differently (PA participation level, age, year group, sports club, gender); a lack of control groups used in the literature; interventions that have been conducted in a clinical population who are at risk of delay or have low autonomy; a lack of follow up studies after interventions to identify lasting effects; a lack of maintenance of the correct delivery throughout the interventions due to non-professionals implementing the intervention (for example, if interventions were too complex for non-professionals to deliver then it would result in the incorrect delivery) ; a variety of  different skills have been focussed on throughout different interventions; data being biased to proactive schools who welcome research and want to improve; and the limited data on this topic that has been based in countries outside of the UK.

The discrepancies that have been highlighted throughout the literature are important and need to be addressed. It is important to understand the relationships between FMS, weight status, age, gender, and PA levels. This leads to some important questions that may have an impact on health, education and well-being in children such as:

1. What are the current FMS levels in UK children aged 6-11?

2. Is FMS predictive of PA behaviour and/or weight status in children?

3. How effective are PA based interventions in schools in positively influencing children's FMS, PA, weight status/body composition and physical self-perception?

This research will aim to answer the above questions which may help influence PE and future health policy, by providing information on: the FMS status of children; the importance of the role FMS has in influencing PA participation; how schools can increase FMS mastery.

### 1.5.10 Study aims, objectives and hypotheses

### Study 1 (Chapter 4). How does age, gender and weight status affect FMS mastery level in British Primary school children?

The aims of this study are to identify the FMS mastery level of a cross sectional sample of primary school children aged 6-11 years in the UK and to identify if variables such as age, gender and weight status display relationships with any individual FMS. The purpose of this study is to understand if children in the UK have mastery of the FMS by the recommended age of six years (Vandaele et al., 2011) and how other individual characteristics may be positively or negatively associated with FMS mastery.

The objectives of this study are;

- To identify mastery level of the eight FMS by using the Process Orient Checklist (POC; NSW, 2003).
- To measure the sprint speed and jump height of the children.
- To assess the children's BMI by measurements of height and mass.

*Research hypothesis:* Children will show a linear relationship with FMS mastery and age. Boys and girls will have significantly different mastery levels of different skills. Children with a higher BMI will have significantly lower mastery of FMS. The subjective measurement will significantly correlate with the objective measurement of the sprint run and the jump.

**Study 2 (Chapter 5). Is current FMS a predictor of current or future PA levels and weight status in British primary school children?**

The aim of this study was to further understand the relationship between FMS and PA levels. There is sparse and equivocal data if FMS mastery level can predict PA levels. The first objective of this study was to identify if variation in PA could be predicted from FMS scores. The second objective was to identify the best combination of previous or current FMS level to predict PA levels.

*Experimental hypothesis:* Mastery of FMS will predict habitual physical activity levels. Current FMS mastery level will be a better predictor of current PA compared with previous FMS mastery level.

**Study 3 (Chapter 6). Can FMS mastery of British primary school children be increased through a six week PA intervention and do any improvements in FMS have positive effects on PA and weight status?**

The aim of this study was to identify if it is possible to increase FMS mastery level in children aged 8-11 years old by replacing one of two statutory PE lessons. A session focused on the development of FMS and to highlight if this has any positive effects on PA level, weight status and physical skill self-perception. The aim of the PA intervention was to provide fun and engaging sessions whilst successfully teaching children how to perform FMS. One of the objectives of this study was to determine whether

the number of children who were classed as having mastery FMS could be increased via an intervention; the second objective was to ascertain if children who completed the intervention were more likely to gain mastery of the FMS compared to the control group. The third objective was to identify if PA and physical self-perception were positively influence over the intervention.

*Hypothesis*: By replacing one PE lesson a week children will show positive changes in FMS mastery, PA and self-perception, however, there will be no change to these variables in children who maintain their two statutory PE lessons.

## 2.0 Overview of Methods

Summerbell et al., (2005) reports that there is limited high quality data to identify the effectiveness of obesity prevention programmes because of different samples, interventions and methods used across studies and between countries. To be able to produce high quality results that could influence a policy change regarding PA guidelines for children, it is vital that validated and reliable methods are used to gain valid and reliable results. In this section, there is discussion of the different methods that have previously been used to collect the data for each variable being assessed in this project. Furthermore, the focus of this research is field based assessment of each variable, therefore field based measures will be discussed.

## 2.1 Assessment of FMS

The overall aim of this research is to identify the relationships between FMS competency, PA level and weight status. There are different methods that have been used across the literature to measure FMS competency and overall motor proficiency. However, it must be considered that just because a test or method is widely used it does not mean it is appropriate for meeting the aim of every study in the field. Throughout the literature, a variety of different FMS have been assessed, these have included kick, catch, throw, balance, vertical jump, hop, side gallop, sprint run, strike, standing long jump, agility run, leap, slide, stationary dribble, underhand roll, skip, dodge, side jump, jumping jacks, roll, turning jump (Derri et al., 2001; Okley et al., 2001;

Okley et al., 2004; Cliff et al., 2007; Harten et al., 2008; Barrnett et al., 2009; Mitchell et al., 2011; Vandaele et al., 2011). The variety of tests discussed below use different combinations of the aforementioned FMS.

Wrotniak et al., (2006) developed a test to assess fine and gross motor skills; the Brumminks Oseretsky test of motor proficiency (BOTMP). The BOTMP was designed for 4.5 – 14.5 year olds. This is a 46 item test divided into eight sub categories (running speed and agility, balance, bilateral coordination, strength, upper limb coordination, response speed, visual motor control, upper limb speed and dexterity). Each item is rated on a two point scale (pass or fail) and the units that each test was measured in are recorded, converted to numerical point score and then totalled to produce sub-category scores. Although this method is suitable for the ages being assessed in the current study (6-12 years), the BOTMP uses an objective measure of each item that is assessed. Although the scores are converted and totalled they are still based on the original objective measure of the skills. By purely measuring the objective outcome of a skill, it risks the assessment of maturation of the child rather than assessing whether they are performing the skills with the correct technique; for example, if a child has a larger muscle mass compared to another child of the same age they may be able to physically throw a ball further due to an increase in physical strength. However, just because they can throw further, they may have the wrong technique, which could potentially affect their performance in later life. Vandorpe et al., (2011) reported that children who were involved in organised PA had significantly better mastery compared to those who were not. In addition, Haywood et al., (2012) stresses the importance of identifying

the developmental stage a child is at for a given skill. By purely measuring the skill objectively it does not allow for this. Furthermore, using the BOTMP the results are totalled into the subcategory which does not allow for individual FMS to be identified as being important components for PA participation and maintaining a healthy weight status. Also, it will not identify the developmental stage of the children for individual skills which has been highlighted as important (Haywood et al., 2012). Wiart and Darrah (2001) suggest that this method is a better indicator of overall motor proficiency, rather than fine and gross motor skills as claimed; therefore it is not an appropriate method to use in this research.

In 2004, Theofili and Simons developed the Korperkoordinations Test fűr Kinder (KTK) to test for MC in children aged 5-14 years old. This method is similar to the BOTMP due to the objective measurements of four items: walking backwards on a balance beam on a variety of widths; hopping over obstacles varying in height; lateral jumping; moving your body sideways with the aid of two boxes. This method has been designed for the age group used within this research. The tasks assessed are objectively measured, again, which could potentially measure the maturation of the child rather than the technique of the skill, similar to the BOTMP (Wrotniak et al., 2006). As discussed in the introduction, FMS are foundations for the larger sporting movements (Haywood and Getchell, 2006), the four tasks assessed in the aforementioned method do not represent the FMS (running, jumping, hopping, kicking, throwing, catching) needed to be able to partake in sporting/physical activities commonly played in the UK (football, netball,

rounders, tennis, gymnastics, dance, rugby). Therefore, this method would not be appropriate for the research in this research.

Henderson and Sugden (1992) developed the Movement Assessment Battery for Children (MABC). This test is spilt into 'the performance test' and 'the checklist'. The performance is comprised of 32 tasks divided into four age bands; 4-6 years; 7-8 years; 9-10 years; 11-12 years. The tasks given to each band get harder the older the child gets. This method also uses sub categories and these are; manual dexterity, ball skill and static and dynamic balance. Again this method covers the ages of the children being used in this research. One of the studies in the research is a one year follow up of the children to assess for any changes in FMS competency. If this method were to be used then as the children change age then they would be given harder tasks to complete and results from the previous year could not be compared. In addition, as part of the research children will be assessed in their school year groups. In the UK the ages of the children in their year group are different to the age bands used in Henderson and Sugden's (1992) MABC, such that different tasks would be given to different children in the same age group. The second part of the MABC is the checklist. This is designed for children aged 5-11 years old. The check list is comprised of 48 items according to relative task difficulty, which is based on whether the child is stationary or moving and whether the environment is stable or changing. The tasks are judged on a four point scale; 0 – very well; 1- just ok; 2 – almost; 3 – not close. Firstly, this method has not been designed for the ages that will be assessed in this research. Secondly, the four point scale is a very subjective measure of the tasks and no criteria is followed to distinguish

between the points of the scale and therefore the score awarded is very much down to personal opinion. For this limitation to be minimised it would require the same person to assess all the skills for the whole sample throughout the research. Even by doing this, the results given on that day could be subjected to mood, arousal and attention levels (Saaty, 2013). If all results were assessed on the same day then again this could be minimised, the current research will be running over a two year period and therefore stricter guidelines are needed to ensure that high quality consistent data is produced.

Folio and Fewell (1983) developed the 'Peabody Development Motor Scales' (PDMS) to identify: the development skill level of a child; the skills that have not been developed; and the skills for future programme. The PDMS was developed for children aged 0-7 years old. There are 170 items that are tested and broken down into five categories; reflexes, balance, non locomotor, locomotor and receipt and propulsion. The items are assessed using a three point scale; 0 – child cannot or will not perform the skill; 1- performance resembles but does not fully resemble criteria; 2 – child performs according to the criteria. Again, this is very subjective, leaving it up to the researcher to decide if the skill performed represents the criteria, and it doesn't give specific components (for example, angles of joints or limbs), similar to Henderson and Sudgen's (1992) approach. Not only is this method not designed for children younger than the samples being assessed throughout this research, but the protocol also involves the assessment of 170 items. With the large sample that will be involved in the current research this is not realistic to complete.

One of the most common tests for motor development is the Test Gross Motor Development (TGMD) (Ulrich, 1984). The TGMD is designed for children aged 3-10 years old. This method assesses 12 gross motor skills which are divided in to two sub-categories; locomotor and object control. Each skill is demonstrated to the children, with instructions, and if the child completes a skill that does not resemble the required skill then an additional demonstration is displayed. The children are also given two practice trials. Skills are comprised of three- five observable criteria and given a score of 1, for pass, or 0, for fail on the presence or absence of each criterion. The sub categories are then totalled. The age that this method has been developed for is not appropriate for the age that will be used in this current research. Although the skills are measured subjectively to strict criteria, the way in which the test is completed is flawed. The children are given coaching points and repeatedly demonstrated the skill. This could potentially measure a child's ability to copy a skill and perform it and with two practice goes a learning effect could occur (Okely and Booth, 2000; Van Beurden et al., 2003; Barnett et al., 2008).

In 2000, Okely and Booth developed the Process Orient Checklist (POC; NSW, 2003). This method of analysis has not been developed for a specific age range. Therefore, anyone's FMS level can be assessed and compared due to the method simply breaking down the technique of each skill. Methods that put an age cap on the assessments of skill levels suggest that children will perform the skills differently as they mature (Henderson and Sugden 1992). No matter a person's age, the technique of skill should not change. It would seem logical to have one assessment method that enables

FMS level to be measured at all ages that can be compared against each other and to determine where each individual lies in terms of mastery.

The POC has been designed to assess eight different FMS that form the basis of the most common sports and PA (Sprint run, side gallop, hop, catch, throw, kick, jump and static balance). Each skill is broken down into five or six criterion which must be present to have mastery of the skill. Children are given one demonstration with no coaching points and no repeat demonstrations, whereby assessing the child's baseline skill level. Due to this method being designed for any age it will be possible to use it in this research and it allows the developmental stage to be determined for the individual skills of the children. Additionally, the skills that are assessed underpin the most common PA for children in the UK (DCMS, 2012). In conclusion this method will be used to assess the developmental stage of FMS in children in this research.

## 2.2 Objective measurement of FMS

By assessing the objective result from a performance of a skill, it allows the relationship with the subjective measurement to be analysed; for example, it will help identify if mastery (for technique) of the sprint run, is associated with a faster sprint speed (for performance) in children? For participation in sport or PA, children's success will often be down to the objective measure of a skill. For example, how fast they can run, how far they can throw, how high they can jump, if they can catch a ball. By having the correct technique of a skill it will aid the objective outcome (eg,

speed/distance). By assessing this it will help justify the use of predominantly using the subjective measurement tool.

The gallop and the hop will not be objectively measured due to the fact the children can either do it or they cannot and it is not a skill that needs to be done at speed for successful participation in PA.  It would be possible to objectively measure the rest of the skills. To assess the kick and throw objectively, a choice between the distance and the accuracy of the kick and throw would have to be decided. For both of these measurements there would not be space in the sports hall where the data collection will be carried out.  Furthermore, kinematics and biomechanical analysis would be needed, which is expensive and labour intensive (Kellis and Katis, 2007; Payton and Barlett, 2008). There is also limited time with each class of children for the data to be collected. The skills that will be objectively assessed will be the skills that can be measure subjectively at the same time.

Balance can be assessed using the Y balance test (Sarchin et al., 2012), this has not been validated in children and it takes a long time to carry out with familiarisation as an essential part of the protocol (Sarchin et al., 2012). Furthermore, the balance that will be measured subjectively is standing on one leg of which the Y balance does not replicate. Therefore, an objective measure of balance will not be used in this research. With the sprint run and the jump it will be possible to measure these skills objectively whilst the children are being videoed for the subjective measurement.  This increases the validity of the results when the objective and subjective measures are being correlated as both results will be taken from the same skill that was performed. These are discussed further below.

**2.2.1 Sprint run**

A quick and easy method for timing a sprint is to time it manually using a stop watch. This method has major limitations. When a human is using a stop watch they have to visually see the person cross the start line, a message then needs to be sent to the muscles to press the start button and again to repeat this process at the finish line. Such a process allows human error to create variation in the sprint time results. Ebben et al., (2009) has reported that manual timing can increase a sprint time by an average of 0.20 seconds (a 6.4% increase) compared to electronic timing. In the current study the children are only running over a 10m distance and 0.2 second variation could have a large impact in the results as the sprint itself should only take around 2-3 seconds.

A more recent method of timing speed is using global positioning satellite (GPS). This can allow for groups of children/people or whole teams to be tested at one time when competing/training if time is an issue or if team players need to be assessed against each other in a game situation. A GPS monitor would need to be worn and these are made to fit adults rather than children (watch straps are large on children), causing problems with them staying on and discomfort for the children. Research has suggested that GPS should be used on distances over 30m (Barbero-Alvarez et al., 2010), yet the proposed research in this thesis will only be looking at a 10m distance, this suggests that it is not advisable to use GPS for this research. The data will be collected in a sports hall with room to only allow one child, at a time, to run safely. When using GPS monitors inside they may not to pick

up the GPS signal needed and unreliable results are produced due to a special error of 1-2m more than outdoors (Elegethun et al., 2006). It would also take a long time to put the monitors onto the children; as a result of this it would be more useful to identify an alternative method.

Electronic light gates are a commonly used and reliable method to assess the time of a sprint (Hetzler et al., 2008). This method eliminates risk of human error. An infrared beam is directed from a device onto a reflector to create an infrared 'light gate'. When the infra-red beam is broken the timer is started. A similar gate can be set up exactly 10m apart and when the second beam is broken in the second gate, the timer will stop. There is no human error in the starting and stopping of the timer. The equipment is portable, easy to use and the children do not need to put on monitors. Therefore, the light gate method (Fusion Sport, Australia) will be used to assess sprint speed in children in this research.

## 2.2.2 Jump height

A very basic method used to assess jump height is the jump and reach method, more commonly known as the Sargent jump (Sargent et al., 1921). This involves a participant standing next to a wall and jumping, reaching one arm up. The participants jump height is calculated by taking the reach height from the jumping reach height. In this research the technique of the jump will be measured subjectively (via the POC) and the height of the jump will be measured objectively; therefore the techniques need to be the same so they can be correlated with each other. The Sargent jump

predominantly uses one arm to power the jump. The subjective measure will require the use of two arms to power the jump and therefore the Sargent jump cannot be used.

Video analysis is a method used to measure jump height. To accurately measure the height of a jump it would involve setting up a triangle that coincides with the 3:4:5 ratios to ensure during the set-up that the camera lens is parallel to the child performing the jump. If the camera is just 1cm out of line then this can cause a parallax error due to the shape and size of the object seeming to be different (Kirtley et al., 2006). Also, if the child performs the skill in front or behind of the plane of motion then that will increase perspective error (Sih et al., 2001). Although perspective error can be decreased by moving the camera back further, the sports hall that will be used to assess the jump height is not big enough for this. In addition, Casartelli et al., (2010) reports that video analysis cannot accurately detect the exact height of the jump and that other methods should be used where possible.

Casartelli et al., (2010) report that using the myo test is a valid and reliable method of recording jump height. This method involves putting a belt around the waist of the child and attaching a portable hand held device on it. A counter movement jump can be selected as one of the tests and it then asks for three jumps. A myo test has an accelerometer mechanism which can calculate jump height. Jump height is determined from the force measurement that is calculated as a result of the acceleration of the jump and the body mass (entered in to myo test first). Flight time is calculated from the force measurement by determining the difference between two time

points; the end of the concentric phase (when the pushing force equals the force of the body weight) and the landing (when the landing force is equal to the force of the body weight). It is then from flight time that jump height is calculated (Nuzzo et al., 2011). The validity of myo test has been widely published demonstrating strong reliability (r=0.85-0.99) (Newton et al., 1996; Jidovtseff et al., 2008; Crewther et al., 2011; Nuzzo et al., 2011). If the device detects something unusual it will ask for an extra trial. The myo test equipment is extremely portable and easy to use and with several set-ups available to use. This allows more than one child to be tested at one time to increase efficiency of the data collection. Therefore the myo test method will be used to assess jump performance in this research.

## 2.3 Assessment of PA

PA is an extremely difficult variable to measure (Dishman et al., 2001). The term PA will be interpreted differently by different individuals. Some people may think that PA is only 'sport' or 'exercise', whereas some will class household chores such as vacuum cleaning as PA. However, PA is described as 'any bodily movement produced by skeletal muscles that results in energy expenditure' (Caspersen et al., 1985, page 216), which can be broken down into occupational, sports, conditioning, household, active transport and other activities (Caspersen et al., 1985). Therefore, the method selected will depend on which type of PA is being measured. This research will look to assess habitual PA levels. To measure habitual PA it is important that measures are taken when children are in school, out of school

and on the weekend. There are many techniques that can achieve this objective and these are discussed below.

## 2.3.1 Self-Report Questionnaires

Burrows et al., (2010) concludes that when it comes to self-report measures in children aged 4-11 years (most ages in this research fall between this age range) parents should complete the recall. Not only are adults subject to demand characteristics and giving socially desirable answers (Burrows et al., 2010; Lee et al., 2010), but the parents would not be able to accurately estimate what and how much activity is completed in school. These limitations of parents reporting on behalf of the children would generate unreliable results. To ensure that children don't have to rely on their recall, questionnaires have been validated that are designed to make them suitable for children. These include questionnaires that provide examples of different types of sporting and leisure time activities to help prompt or remind children of what they did (A short questionnaire for the measurement of habitual physical activity; Baecke et al., 1982). Although this would help children to recall what they did, the youngest age bracket would not have the cognitive ability to recall everything that should be included and to be able to distinguish between types of PA. In addition, the current research is assessing habitual PA rather than distinguishing types of PA. A systematic review conducted by Chinapaw et al., (2010) identified 61 versions of self-report PA assessment tools from 54 research studies. From these 61 questionnaires, Chinapaw et al., (2010) concluded that none of them were

deemed a valid or reliable assessment method for PA in children. Therefore, self-report measures will not be used in this research.

## 2.3.2 Accelerometers

Accelerometers have been widely used in research to measure children's PA level (Trost et al., 2001; Cliff et al., 2007). The acceleration is the change in velocity over time, which will quantify the volume and intensity of the movement (Freedson et al., 2005). When accelerometers were first developed, they could only measure acceleration on the horizontal axes. However, due to the advancements in technology accelerometers can now measure movements in three axes/dimensions to determine if that person is standing, lying, sitting, or not wearing the device (Hawk, 2012). Therefore, the duration and intensity of PA can be determined. The raw acceleration signal is often translated in to a metric that is related to either a biological variable (energy expenditure) or PA patterns (low/high) (Freedson et al., 2005). Translating these raw acceleration signals is difficult due to the technology being based on biomechanical principles and converting it to biological measures such as energy expenditure. This is further complicated in children as growth and maturation can skew the associations (Freedson et al., 2005). Studies have developed equations for the calculation of energy expenditure from accelerometry (Sallis et al., 1990; Trost et al., 1998; Payau et al., 2002). Payau et al., (2004) has since validated these methods using a portable gas analyser which concluded that these aforementioned equations will underestimate energy expenditure by 19-24% depending on the model. Gerda et al., (2013) identified that there are no cut off points for young

children for the $GT_3X$ accelerometers. Freedson et al., (2005) have identified that cut points between three and six METs (low and moderate intensity; Jette et al., 1990) are substantially different between studies, making them incomparable. More attention in future research needs to focus on standardising interpretation of acceleromtery data to make it comparable within research (Freedson et al., 2005).

Payau et al., (2004) identifies that accelerometry can distinguish between sedentary, light, moderate and vigorous activity but cannot accurately predict them. Most studies that use accelerometers only report the MVPA (Van Beurden et al., 2003; Cliff et al., 2007). Westerterp and Plasqui (2004) reports that it is the low and vigorous activity that is the main contributor to overall PA. In this research, the aim of overall habitual PA is desired and information on intensity and type is not needed at this stage. Also, this equipment is very expensive and with the large sample size used in the research in this thesis it will not be possible to use this technique.

### 2.3.3 Pedometers

Pedometry is a common and popular method used within research to assess PA status due to it being more cost effective compared to accelerometers, easy to use and administer (Trost et al., 2007). The use of a pedometer as a measure of PA in children has been widely validated across the literature (Leenders et al., 1997; Eston et al., 1998; Trost et al., 2000; Tudor-Locke et al., 2002; Riddoch et al., 2004; Trost 2007; Clemes and Biddle, 2013). Leenders et al., (1997) assessed if the placement of the

pedometer would affect the result output and reported no difference in result dependent upon the placement of the device. This supports the use of pedometers in children, as they will be more likely to move the placement of the device compared to adults. Leenders et al., (1997) also reported that there was a significant change in step counts when speed on a treadmill was increased; highlighting good sensitivity of the pedometer to change in speed/activity when a child is wearing it. Children's PA is very sporadic; walking is the main feature of utilitarian physical activity, of which pedometers are sensitive enough for walking in all its forms (Tudor-Locke et al., 2004). Eston et al., (1998) reported a significant correlation of r=0.95 between pedometry and oxygen consumption, indicating that pedometry can accurately report PA in children. Tudor-Locke et al., (2002) conducted a review that correlated pedometry with other methods of PA assessment; Accelerometers, r=0.86; DLW, r=0.6 and self-report questionnaire, r=0.02-0.94. These results highlight that the first two aforementioned methods show a significant correlation with pedometry and these methods have been previous validated with in literature (discussed in section 2.3.1 and 2.3.3), therefore increasing the reliability of the use of pedometers in research. In section 2.3.2, it highlights that self-report questionnaires are not a reliable method to assess PA, particularly in children, thus explaining why Tudor-Locke et al., (2002) predominantly reports weak non-significant correlations between the pedometry and self-report questionnaires. Tudor-Locke et al., (2002) concluded that pedometers are suitable substitute for accelerometers when raw movement is desired. Clemes and Biddle (2013) report that pedometers are a valid and reliable measure of PA in children but only in

children who are aged five years and above. Although pedometry cannot give information such as intensity and time, the aims of the research in this thesis is to identify habitual PA and change in PA over time. Pedometers have been suggested as a reliable method to meet this aim throughout the literature (Tudor-Lock et al., 2002; Trost 2007). A limitation of pedometers is that the authors/researchers is unaware if children have not worn it or have tampered with it (shaken it). To overcome this limitation Rowe et al., (2004) suggests that when pedometers daily step counts are reported as being less than 1000 steps or more than 40,000 steps those participants should be excluded from the data as these values are likely to be unreliable. Data will be collected over two weekend and two weekdays will be used to account for differences in PA behaviour when at school and home. This method has been validated within literature (Trost et al., 2000; Duncan et al.,2007).

Not only has the method of pedometers been validated, but the type of pedometer also. There are three basic type of mechanism that pedometers use; the first is a spring suspended lever arm that works by a metal on metal contact to conduct an electric current. The horizontal spring suspended lever moves up and down in response to the hips vertical acceleration and a step is registered (Crouter et al., 2009). The second is a magnetic reed proximity switch. This works on a horizontal spring lever arm but uses a magnet to create a magnetic field by the overlapping of pieces of metal in a glass cylinder to register a step (Schneider et al., 2004). The final mechanism is an accelerometer type that consists of a horizontal beam and piezo-electric crystal. The walking motion generates a sinusoidal curve when vertical acceleration is plotted against time. This mechanism uses zero

crossings of the acceleration vs time curve to detect steps (Schneider et al., 2004).

The most reliable method is the final one described that used the accelerometer type mechanism as it is not subject to tilt angle that the other mechanisms are (Crouter et al., 2005). The pedometers that use these methods are very expensive compared to the other types (Crouter et al., 2005). Although research has identified that this is the most reliable mechanism the spring suspended lever arm that works by a metal on metal contact to conduct an electric current has also been validated throughout literature. This mechanism is used in the Yamax Digi-Walker (SW 700) and this type has been shown to give the mean step counts that were within 1% of actual steps (Crouter et al., 2003). At walking speeds ranging from 54 to 107 m·min$^{-1}$, the SW-701 was the only one out of 10 models that did not differ significantly from actual steps taken (Crouter et al., 2003). This pedometer model was found to have similar accuracy in normal weight, overweight, and moderately obese individuals (Swartz et al., 2003).

Considering the aim of the research that will be conducted in this research and the supporting evidence for the reliable use of the Yamax Digi-Walker (SW 700) pedometer in this section, this method will be used for the assessment of PA in this research.

## 2.4 Assessment of Weight Status

### 2.4.1 Bioelectrical impendence

Bioelectrical impedance is a popular method used to identify BF%. This works by sending electrical impulses constant low level alternating current which results in an impedance to the spread of the current that is frequency dependent (Lukaski et al., 1985). Intra- and extracellular fluids that behave as electrical conductors and cell membranes that acts as electrical condensers. The current passes mainly through the extracellular fluid while at higher frequencies (500- 800 kHz) it passes through the extra- and intracellular fluids (Thomasset, 1962). From this total body water can be determined and Hoffer et al., (1969) discovered the relationship between total body water and fat free mass. Reliability coefficients against skinfolds and hydrostatic weighing range in research between $r = 0.957–0.987$ demonstrating strong validity (Lukaski et al., 1985; Jackson et al., 1998)

This method is very popular as it is portable and can be taken into the field. This method is based on the conductivity of the tissue which can be affected by hydration levels, last meal eaten, previous exercise, body position and body temperature (Kyle et al., 2004). Each of these variables will be difficult to control for in the children and due to repeated measurements being taken over two years it will not be possible to ensure that the conditions are the same each time. In addition when girls reach puberty they will develop breast tissue which can skew BF%.

## 2.4.2 Body Mass Index (BMI)

BMI is the principal method for identifying an individual's weight category; underweight, normal weight, overweight, obese and morbidly obese (<18.5, 20-25, 25-30, 30-35, >35kg/m$^2$ respectively (WHO, 2014)). However, BMI does not identify or distinguish BF% and fat free mass. Due to BMI not measuring BF% the method can often be flawed (Nevill et al., 2006). An extreme case is a 27 year old NFL American football player who has <20% body fat percentage but has a BMI of 39.6 kg/m$^2$ (Prentice and Jebb, 2001), which would put him in the severely morbidly obese category. As with athletes, children are susceptible to having a skewed BMI. This is the result of muscle groups developing at different stages, lack of growth spurts or 'puppy fat' still remaining, thus highlighting the importance of interpreting BMI with caution. Cole et al., (2000) stresses that when using BMI on children it should be used as a guide and not an absolute reading. BMI is often favoured due to the fact that it's quick, easy and does not require highly trained staff. The BMI standard cut offs mentioned at the beginning of this section are used as guide for adults and should not be used for children as they are still growing. Cole et al., (1990) developed a reference curve for children's BMI to control for age and sex when determining a child as being normal weight, overweight or obese. If children fall into the 85th or 95th centile then they will be as classed overweight or obese (Cole et al., 1990), respectively. A z score can also be calculated which can identify how far away a child is from a 'normal' weight for their age and sex (Cole et al., 1990). By using these techniques it can help reduce the limitations of BMI. BMI will be used in this research because it is the recommended method to

classify weight status by the International Obesity Task Force (IOTF) (Cole et al., 2000). Furthermore, it is the method in which government assess children who are overweight and obese in the UK as part of the National Children's Measurement Programme (NCMP) (The Health and Social Care Information Centre, 2012) and is widely used in the literature (McKenzie et al., 2002; Graf et al., 2004; Okley et al., 2004; Southall et al., 2004; Erwin and Castelli, 2008; Cliff et al., 2009; D'Hondt et al., 2009).

## 2.4.3 Skinfold thickness

A calculation using the sum of skinfold thickness is a common method to distinguish BF%. This can be determined by using skinfold callipers to measure the thickness of skinfold thickness at various sites in the body and has been validated throughout literature, reporting correlations up to r=0.9 when comparing with the gold standard measurement of dual-energy X-ray absorptiometry (Wickramasinghe et al., 2008; Hoffman et al., 2012; Freedman et al., 2013). By assessing skinfold thickness, it cannot be affected by other variables such as, hydration and temperature, unlike previous methods discussed. This method is often favoured due to it being portable, cost effective and quick to complete. This method can easily be done in a school setting. There are many body sites that can be measured for skinfold thickness, with the equation used to calculate the BF% depending on the sites chosen.  Choice of site for skinfold measurement can depend upon age and sex, with some measures being invasive. Therefore, when conducting research on children the selection of skinfold sites must be

considered carefully and chosen for the specific population group being assessed (Hoffman et al., 2012). Slaughter et al., (1988) provides an equation that can calculate BF% in children (Heyward and Wagner, 2004) by using just two body sites; medial calf and tricep. Sardinha et al., (1999) has reported that assessment of skinfold thickness at the tricep is the most appropriate way to identify BF% in children. Therefore, this method will be used in this research due to its non-invasive, portable and accurate nature.

## 2.5 Physical self-perception of skill competency

Physical self-perception has been identified as having an important influence on FMS level and PA (Barnett at al., 2008; Stodden et al., 2008). This variable will be assessed as part of the intervention in study 3, to identify benefits the intervention could potentially have on physical self-perception. It is a psychometric measure, which makes it difficult to obtain reliable results as each value is dependent on the participant being truthful. A further issue that arises when measuring self-perception in children is that they must have the cognitive ability to understand what is being asked of them and for them to understand how important it is to be honest. Stodden et al., (2008) identifies that children do not have the cognitive capability to accurately perceive their AMC until they reach middle (7 years) to late childhood (Harter, 1999). Children in the intervention will range from 8-10 years, therefore, according to Stodden et al., (2008) they will be cognitively developed enough to accurately perceive their motor competence.

### 2.5.1 Interviews

One method of measuring a child's self-perception is to conduct interviews with the children (Ridgers et al., 2012). This qualitative data collection would be open to interpretation and children would be more susceptible to giving socially desirable responses as they will be giving direct answers to a person. In addition, this process is very time consuming which would make it prohibitive for the large sample size planned in this research. Due to the large sample size a sub-sample could be interviewed, however, due to school constraints this was deemed too disruptive to complete.

### 2.5.2 Questionnaires

The other option to assess a child's self-perception is to use questionnaires. Poulsen et al., (2011) uses the Self-Description Questionnaire-1 (SDQI) which is a multidimensional measure of preadolescent's self-concept. It measures 76 items, broken down into 11 subscales and marked on a one – five (true-false) continuum. This measure has also been validated by Byrne et al., (1996). Although a very reliable (Internal consistency scores are high with alpha coefficients ranging between 0.8 and 0.9) measure to use, this research is exploring self-perception of the physical skill level and this questionnaire focuses on a large range of variables such as physical appearance, peer relations, reading, mathematics, school in general and global perception. Not only are these topics irrelevant to the current research topic, but given the limited time with

the children, it would not be possible to administer a long questionnaire such as the SDQI.

A questionnaire that dominates the research to measure self-perception is Harter's (1982) Original Perceived Competence Scale for Children (PPCSC) consisting of 26 self-efficacy questions (Jones et al., 2010; Robinson 2011; Breslin et al., 2012). Harter's (1982) original PCSC measured cognitive, social, physical and general self-worth characteristics. Since then, modifications have been made to create a PE Efficacy Scale which was validated in 1985 (Harter, 1985). The modified version assesses ten questions because they were shown to have good discrimination between self-efficacy levels (gymnastics, dance), or were activities children perform in PE lessons (Horn and Hasbrook, 1987; Duncan and Duncan, 1991; Kimiecik, et al., 1996).The wide use of this questionnaire is down to its unique scoring system. The questionnaire gives two situations and the child has to decide which one they are and then state whether that situation is 'really true for me' or 'sort of true for me'. By using this technique of scoring the questionnaire it decreases the likelihood of gaining socially desirable responses by not using any negative words in the scoring system unlike other most other scales (Horn and Hasbrook, 1987; Duncan and Duncan, 1991; Kimiecik et al., 1996). The modified PCSC is ten questions long and asks about everyday sporting/physical activities that the children are likely to participate in which, use FMS. Thus, this questionnaire can be delivered in class groups, making it time efficient. The PCSC will be used for research in this thesis.

# 3.0 General Methods

## 3.1 Recruitment

The participating schools were chosen with the assistance of Coventry City Council's lead advisory teacher for PE. The schools were chosen that sat in the mid-range (50-59%) of electoral wards for deprivation and socio-economic status within the city and nationally (Coventry City Council, Key Statistics, 2012) as a means to ensure the extremes of affluence and deprivation did not confound the results of the study. In addition it was ensured that there was no specialist PE programme, such as interventions or specific focus, in place at the time of testing.

Once the schools had been chosen the project coordinator was given the contact details of the individual schools PE coordinators. Letters were then sent to each school to invite them to take part in the research project (Appendix I). The letter included a description of the project and the contact details of the project coordinator for any further questions. Once schools had accepted the invitation to participate in the research project, meetings were arranged with the PE coordinators of each school. In these meetings, arrangements for a timetable suitable for the school for the sessions to take place were made and distribution of the informed consent form to the children and their parents/guardians was organised. It was decided that the research interactions with the children would take place within their dedicated PE lessons so that it did not disrupt the teaching of other core subjects.

## 3.2 Ethics

Ethics approval (Appendix I) was obtained from Coventry University's Ethics Committee prior to each study. Informed consent and information sheets were sent out to parents of each participating school (Appendix II). Parents and children were informed that they could withdraw at any point in the study. Data was not collected from any children until all signed consent forms had been returned. If a child returned a consent form within which the parent/guardian stated that their child's data was not to be used, then that child was still allowed to partake in the PE session, however no data was recorded for that child. A risk assessment of each school sports hall was undertaken to ensure that children were at no greater risk than they would be in an ordinary PE lesson. Before entering each school, CRB certificates and identification was presented by each researcher and recorded with the receptionist of the school to comply with legal legislation. Children gave their assent to partake in the research but were also reminded that they did not have to participate in anything if they did not wish to and were assured that all information was confidential and that their names would not be used. To ensure that results remained anonymous, children were given a number to be identified by; names were not used at all. In each session of data collection children wore a sticker with their number on: 1) so that they could be identified on camera; 2) so that the data that was recorded in the sessions could be coded by the numbers and not names; 3) to make children feel at ease that their results were not going to be related directly to their name.

Data was stored in a locked filing cabinet or on a password locked Coventry University computer.

## 3.3 Fundamental Movement Skill Assessment

Prior to the assessment of any skills (Subjective/objective) a five minute cardiovascular warm up was conducted with the children. This included the children using the space in the hall to travel around in. The researcher shouted out different numbers which coded for a different travelling method; 1, walking; 2, running; 3, sprinting; 4, touch the floor; 5, jumping on the spot.

### 3.3.1 Subjective measurement

FMS was assessed using the guidelines taken from the New South Wales 'Move it Groove it; Physical activity in primary schools: Summary Report' (2003). The POC was taken from this report to assess the FMS (Appendix III). This checklist is comprised of eight different FMS; Sprint Run, Side Gallop, Hop, Kick, Catch, Overarm Throw, Vertical Jump and Static Balance. Each skill is broken down into five or six components, which when performed must all be present to demonstrate complete mastery of the skill.

To collect the FMS data testing was carried out in a school sports hall. A team of eight trained researchers (according to the Move it groove it guidelines; NSW, 2003) assisted in the recording of the FMS. The eight FMS were split into locomotor (sprint, hop and gallop) and object control and static (balance, jump, catch, kick and throw) skills. The reason for splitting the skills

into two groups was not only for efficiency of collecting the data but also because the two categories needed different camera angles to ensure that all components of the skills were visible on playback. For the static skills, the camera was set up on the coronal plane (Figure 3.1), whilst the locomotor skills had the camera set up on the sagittal plane (3.2), following guidelines by Knudson and Morrison (2002). For all eight FMS, each skill was demonstrated once with no coaching points in accordance with 'Move it Groove it' (NSW, 2003) guidelines. Each child performed each skill three times.

Figure 3.1 Children performing the balance skill in the coronial plane to the camera.



Figure 3.2 Children performing the side gallop in the sagittal plane to the camera.

Locomotor skills were performed over a marked 10m distance. Although the POC states that the run should be completed over a 20m distance, this was not possible due to the size of the sports hall. This test was adapted to 10m, with the technique of the run still being assessed over a 10m distance. Children were asked to sprint between the two points as fast as they could. Children were asked to hop on one leg between the two points. Children were asked to gallop sideways, facing the camera, between the two points.

For the assessment of object control and static skills, three cones were placed in a line in front of the camera. One child would stand by each cone and perform one skill three times. This was done to increase the efficiency of data collection. Once the three trials had been completed the next three children would take their place by a cone. For static balance, assessment children were asked to stand on one leg for 10 seconds. For the vertical jump children were asked to jump up as high as they could, using their arms. For the kick, children were asked to take three steps away from the ball and then kick the football in a forwards direction. For the catch, children were thrown a soft tennis ball from 3 m and were asked to catch it. For the throw, children were asked to throw a tennis ball over arm to the researcher who was standing in front of them (NSW DoH, 2003).

Each FMS was video recorded at 50 frames per second (Sony video camera, Sony, UK, model: HDR HC9E) and subsequently edited into single film clips of single skills on a computer using Quintic biomechanics analysis software (Quintic Consultancy Ltd, UK). The skills were also analysed using this software, enabling the videos to be slowed down, magnified and

replayed. The POC was used to determine the mastery level of the skill. This method was used as it more accurately identifies specific topographical aspects of the movement, such as the technique and position of different body segments (Ulrich, 2000). Furthermore, this method was originally validated in 42 children (age range from 4-12 years), which involved a 7 day test retest cycle, producing reliability estimates for each skill (alpha coefficients of 0.74, $p<0.01$; Okely and Booth, 2000). One this had been completed the POC was trialled across 26 primary schools over a three month period, producing an 85% agreement with the trained experts (Okely and Booth, 2000).

When the child performs each skill if they demonstrated all components of the skill then 'mastery' was given. If the participant demonstrated all but one of the components of the skill then 'near mastery' was given. If more than one component were deemed to be missing then the participant would have no mastery of the skill (Move it Groove it, NSW, 2003). In addition to this categorical analysis a percentage of mastery was calculated. This percentage was calculated for two reasons; firstly, the FMS teacher manual (Move it Groove it, NSW, 2003) explains that each component is not of equal worth, with different skills being composed of a different number of components (Barnnett et al., 2009). Therefore, by calculating a percentage it allows for them to be compared on the same scale. Secondly, by displaying a percentage it identifies how far away a child is from mastery because children who are close to having near mastery are classed in the same category as the children who have no mastery at all.

A percentage was calculated for all three attempts and the mean of these three attempts were calculated to provide an overall percentage used for analysis. By using the mean it accounts for differentiation between attempts. Furthermore, previous methods to assess FMS ensure that they use the results from each attempt to generate a score for that FMS (Ulrich, 2000; Okley and Booth, 2004 Barnett et al., 2008; Vandaele et al., 2011).

Pilot data on 52 children (26 girls and 26 boys) with a mean age and SD of 8.4 ± 1.6 years was collected. Children performed each of the eight FMS three times. Repeatability between performances was analysed. The Cronbach α values indicated consistency across repeated trials for all eight FMS: balance α= 0.834, throw α=0.847, catch α=0.753, kick α=0.926, run α=0.886, gallop α= 0.936, hop α= 0.841 and jump α= 0.761. Repeated measures ANOVA was also conducted and identified the measurement scale as stable due to no significant difference between trials of all eight FMS: balance p=0.459, throw p=0.098, catch p=0.621, kick p=0.695, run p=0.524, gallop p=0.110, hop p=0.613 and jump p=0.134.

In addition, if the participant demonstrated all components of the skill then 'mastery' was given. If the participant demonstrated all but one of the components of the skill then 'near mastery' was given. If more than one component was deemed to be missing then the participant would have no mastery of the skill (Move it Groove it, NSW, 2003). Prior to analysis inter and intra rater reliability analysis was performed for all the FMS between each researcher and the lead researcher. Individual scores for the latter can be found in each study.

### 3.3.2 Objective measurement

The sprint run and jump were both measured objectively as time (seconds) and height (m) respectively.

A ten metre sprint run was timed using Smartspeed gates (Fusion Sport, Australia). Two laser gates were set up ten metres apart. The participants started 1m behind the gate to ensure consistency and that a light beam wasn't broken early. Due to the sprint being shortened to 10m it is an acceleration test. However, this still allows for the time of the sprint to be compared with the technique of the sprint run.

The children were asked to sprint through the two gates. When the beam was broken in the first gate the timer would start and when the second beam was broken in the second gate timing would stop. The children had three attempts, which were recorded straight onto a spreadsheet. The fastest time was taken for analysis (Hands, 2008)

The height (cm) of the vertical jump was measured using a myo test (Myo test, Rue de la Blancherie, Switzerland, model: myo test pro) recommended by Bubanj et al., (2010). The children's height (m) and mass (kg) was entered into the myo test device. The myo test device was attached to a belt on the waist of the participant. It would beep and then three consecutive jumps were performed. Children were asked to jump as high as they could, using their arms (countermovement jump). The maximum jump height for each child was recorded on to a spreadsheet (Hands, 2008). If children did not use their arms, they were not asked to repeat the jump, as this would be classed as feedback and disrupt the subjective analysis of the

skill. For example 'driving the arms upwards' is a component for the jump in the POC.

## 3.4 Anthropometric measurements

Date of birth was obtained from the school and recorded. The anthropometric measurements were carried out in the sports hall prior to the performance of the FMS. Children wore shorts and t-shirt and shoes were removed for these measurements.

Height was recorded to the nearest centimetre using a stadiometer (SECA Instruments Ltd, Germany, Model: SECA213). Children stepped onto the stadiometer with bare feet facing away from the measure. Children were asked to stand tall and have their chin parallel to the ground with eyes looking forward (Frankfort horizontal plane; Thompson et al., 2009). If children struggled to get into this correct position then the researcher would guide the child's head to the correct position with their hands upon that child's consent. Once the child was in the correct position the measurement was taken and recorded. This method is recommended by Norton et al., (1996).

Mass was recorded to the nearest 0.1kg using electronic scales (SECA, Instruments, Ltd, Germany, model: SECA877). Children stepped onto the scales with their head up, looking forward and their weight distributed between both feet. Once the child was stable and the digital

display gave a constant reading, mass was recorded. This method is recommended by Norton et al., (1996).

BMI was calculated as kg/m$^2$ and converted to z scores using the 1990 reference curves which control for age and sex, to identify overweight and obese children (Cole et al., 1990). Children were classed as overweight if they were in the 85th centile and obese if in the 95th centile (Cole et al., 1990). Weight status was used as a variable in each study.

Body fat percentage was calculated using skinfold body calliper readings using Harpenden callipers (Baty International, UK). Readings were taken from two sites; tricep and medial calf (Slaughter et al., 1988). To mark the point on the tricep for where the measurement was to be taken for the tricep, the half-way point was identified between the superior aspect of the radius and acromiale landmark. Once this half-way mark was identified with a tape measure the midpoint of the tricep was identified using the human eye and the calliper reading was taken (Thompson et al., 2009).To cite the point on the medial calf this reading was taken at the point of the largest circumference of the gastrocnemius on the medial side of the leg. A tape measure was used to identify this landmark (Thompson et al., 2009).

A reading from each site was taken and then repeated a second time. If there was a difference ≥ 10% between the two skin fold measurements for one site then a third measurement was taken to ensure high validity of the readings (Thompson et al., 2009). An average was then taken from the two readings for each skinfold site. The Slaughter et al., (1988) skin fold equation (BF%= (0.735*(Tricep+Medial Calf))+1) was used to calculate each child's

BF%. The same trained researcher took the skin fold measurements each year to maintain consistency and the technical error of measurement at the tricep and medial calf was 4.57% and 4.12% respectively showing appropriate intratester reliability. This method of measuring body fatness, to determine weight status, is widely used in children (Lahti-Koski and Gillb, 2004).

## 3.5 Organisation of data collection sessions

All data collection took place in the schools' sports halls. At the beginning of the session, the anthropometric data was collected. This was separated into four stations; 1) height, 2) mass, 3) skinfold callipers, and 4) jump height. There was one researcher on each station and one child would visit each station, one at a time. This enabled results to be kept discrete from other children to be sensitive to any insecurity's the children might have. Where possible, the same researcher would be on the same station each week to keep the results consistent. Once all the anthropometric data had been collected each class was lined up and split into two groups. One group would complete locomotive skills (sprint, gallop and hop) and the other group would complete the stationary skills (balance, jump, kick, catch and throw). Once each group had completed the skills they were swapped over. Between different schools the length of their PE lesson would differ and therefore it would vary as to how many sessions it would take with the children to complete all the data collection.

## 3.6 Physical Activity Assessment

Habitual PA was measured using pedometer step counts. Children were given a pedometer (Yamax Digi-Walker; SW 700) on a Wednesday. The instructions of how to use the pedometer, when to wear it and when to record the steps were all explained to a class of approximately 30 children at a time. The children were given a sheet which contained: instructions on what to do; their individual unique number so the children could be identified; a table to record the steps per day with a comment box to record time that the pedometer was not worn; and the pedometer number that the child had been given (Appendix IV). Children then had a day to practice using the pedometer, this controlled for the novelty effect when children first get a pedometer and will explore with it, for example shaking it. Following this, children were then required to record their steps on Friday, Saturday, Sunday and Monday, therefore consisting of two weekdays and two weekend days (Riddoch et al., 2004). Sheets and pedometers were then collected the following Tuesday. Each class and each school kept to this same template to ensure consistency. Children who did not have all four days of analysis were not included in the analysis. Children were given diaries to record with parents when they did not wear the pedometer and any children who had values <1000 steps or >40,000 steps per day were excluded from the analysis (Rowe et al., 2004, Clemes and Biddle, 2013) Once data had been inputted into Microsoft Excel, an average daily step, an average weekday step and an average weekend day step was calculated for further analysis.

## 3.7 Children's self-perception of skill ability assessment

The PPCSC (Harter, 1985) was completed in a classroom with the project coordinator and a class teacher (Appendix V). The structure of the questionnaire was explained to the children and they were asked to concentrate on their own answers and to be as honest as they could be. The project coordinator read each question aloud to the children. The administration of the PPCSC followed the recommended guidelines proposed by Harter (1985) which has also been used in other literature (Breslin et al., 2012). Again, names were not used and the child's number was put at the top of the questionnaire. Children were reassured that no one would see their answers. Children were free to ask questions to the project coordinator and the class teacher, who had explained how to use the questionnaire. This questionnaire was completed prior to the intervention, post intervention and in the six week follow up test.

## 3.8 Statistical analysis

The Statistical Package for Social Sciences (SPSS inc, version 20) was used for all analysis and statistical significance was set at P=0.05. The individual statistical tests for the individual studies are reported in the experimental study. All graphs/figures were created using Microsoft Excel 2010.

## 4.0 How does age, gender and weight status affect FMS mastery level in British Primary school children?

### 4.1 Introduction

In 2012 it was reported that only 32% of boys and 24% of girls aged 2-15 years old meet the recommended PA guidelines (British Heart Foundation, 2012) of 60 minutes of moderate to vigorous physical activity (MVPA) per day. These statistics are likely to be linked to the childhood obesity epidemic, where in the last 16 years obesity rates have increased by 22% and 32% in boys and girls respectively (National Obesity Observatory, 2012). Obesity is multi-faceted and does not just affect the aesthetics of an individual, it has multiple long-term implications and is the cause of many other physiological diseases, such as; hypertension, type II diabetes, coronary heart disease and strokes (Graf et al., 2008).

Stodden et al., (2008) have produced a model that identifies FMS as being a key underlying factor that can influence PA and, in turn, weight status. FMS are the basic skills that form the prerequisites for sporting and physical activities (Gallahue and Ozmun, 2002; Barnett et al., 2008). If these FMS are not mastered, then children will not be able to perform the larger gross motor skills that involve performing several basic FMS at one time, which in turn contributes to PA and sporting performance. Haywood and Getchall (2002) emphasize that these FMS must be taught and practiced, and do not develop naturally. Research has identified a direct link between the ability to perform FMS and a higher PA level (Okely et al., 2001; 2004;

Vandorpe et al., 2011). This increase in PA level will then promote maintenance of a healthy body mass (Stodden et al., 2008). This explanation of the mechanisms by which weight status is associated with FMS has been evidenced. Studies have reported that children with a larger BMI will have a lower FMS competency compared to their normal weight counterparts (Okley et al., 2004; Graf et al., 2004; Southall et al., 2004; Erwin and Castelli, 2008; Cliff et al., 2009). Stodden et al., (2008) highlights that FMS is the prerequisite for PA which influences weight status (BMI); therefore if BMI has an effect on certain FMS than future PA programs may need to be targeted to these skills in the overweight and obese population. If adequate mastery of FMS is a facilitator of habitual lifelong PA then failure to master such FMS may become a subsequent barrier to PA and sports participation from childhood into adolescence and adulthood, however additional research is required to come to this conclusion.

Despite prior studies that have examined FMS in Australian children, there is sparse data available on FMS mastery and weight status in UK children. Although children in Australia are comparable to English children as they are predominantly white Caucasian (Australian Bureau for statistics, 2011; Office for national statistics, 2011), environmentally they are different.

The data collected in Australia is predominantly from one area; New South Wales (NSW) (Okley et al., 2001; 2004; Barnett et al., 2009; Barnett et al., 2009; van Bearden et al., 2003; Hands 2003). Average temperatures in NSW, Australia are $26^{o}$C and $16\,^{o}$C in summer and winter respectively, with 125 days of rain on average per year (Bureau of Meteorology, 2014). In comparison, England is much colder ($15.6\,^{o}$C and $4.4\,^{o}$C in summer and

winter, respectively) and on average has more than twice as many days rain per year (268) (Department for environment, 2012; CRRSF, 2014). Therefore, the types and location of activities will vary between countries which potentially could affect the development of FMS, PA level and weight status. Cleland et al., (2008) reports that children who spend more time outdoors can contribute significantly to their overall PA level compared to when spending time indoors. When participating in PA outdoors the intensity is higher, which has been suggested as being important for the development of FMS (Vandaele et al., 2011). Therefore, with better weather in NSW compared to England it is likely that children will be able to spend more time outdoors in Australia, as long as sufficient precautions are taken with regards to the sun, contributing more to their PA levels and/or increasing the opportunity to learn and develop their FMS.

Due to the results highlighted in the research conducted on Australian children in FMS, PA and weight status (Okley and Booth, 2001, Okely et al,. 2004; Barnett et al,. 2008), Australia have reformatted their curriculum which involves the 'acquisition of movement skills, concepts and strategies that enable students to confidently and competently participate in a range of physical activities' (ACARA, 2011). If similar results are found in the UK, it could be important to influence children's PE curriculum in school. As of 2014, England's National Curriculum for PE does include the teaching of FMS; it only includes one sentence stating that 'pupils need to develop FMS' (DoH 2013). There are no goals for which ages the skills should be mastered by and no guidelines of specifically what, and how, the FMS should be taught or tested.

Due to the low numbers of children participating in the recommended PA guidelines, this research is vital to clarify where interventions should be introduced to help improve FMS, increase PA levels and decrease weight status in British Primary school children, to help prevent physiological and psychological diseases in the long term.

The aim of this study was to examine the relationship between FMS and weight status, determined by BMI, in a sample of British primary school children taking into account year group and gender differences.

### 4.1.1 Hypothesis

*Experimental hypothesis:* Children will show a linear relationship between FMS mastery and age. Boys and girls will have significantly different mastery levels of different skills. Children with a higher BMI will have significantly lower mastery of FMS. The subjective measurement will significantly correlate with the objective measurement of the sprint run and the jump.

## 4.2 Methods

### 4.2.1 Sample

This study was carried out in a primary school in Coventry in January 2011. Originally, 292 children from Year groups 2-6 (aged 6-11 years old) were recruited for the study. There were 11 children who did not partake in

the research, thus the final sample size was 281 children (129 boys and 152 girls; aged 6-11 years, mean age 8.4 ± 1.6 years). The purpose of assessing five different year groups was to identify if a trend was apparent throughout the primary school years. The rationale behind starting with year two children (age six years old) is that research states that all FMS should be mastered by children of this age (Vandaele, et al., 2011). By assessing the children at this stage and onwards, any deficiency in movement mastery can be targeted for future intervention. The school that was chosen sat in the mid-range (50-59%) of electoral wards for deprivation and socio-economic status within the city and nationally (Coventry City Council, Key Statistics, 2012) as a means to ensure the extremes of affluence and deprivation did not confound the results of the study. In addition it was ensured that there was no specialist PE programme, such as interventions or specific focus, in place at the time of testing.

### 4.2.2 Ethics

Following Coventry University's ethics committee approval, informed consent and information sheets were sent out to parents of the participating school. Data from the children was only used if they had returned the signed informed consent. Parents and children were informed that they could withdraw at any point in the study.

### 4.2.3 Fundamental Movement Skill (FMS) Assessment

#### 4.2.3.1 Subjective measurement

Children performed eight FMS (run, hop, gallop, kick, catch, throw, balance and the jump). For a full description on how the FMS were assessed refer to section 3.3.1. Prior to analysis, inter and intra rater reliability analysis was performed for all the FMS between each researcher and the lead researcher and this was checked again at the end of the analysis to ensure consistency. Inter rater reliability was 90.3% and intra rater reliability was 97.6% demonstrating good reliability (Jones et al., 2010).

#### 4.2.3.2 Objective measurement

The sprint run and jump were both measured objectively for time (sec) and height (m) respectively. For a full description on how the objective measurement of FMS were assessed refer to section 3.3.2.

### 4.2.4 Anthropometric measurements

Children's body mass and height were measured to calculate BMI to be used to classify weight status. For a full description on how BMI was assessed refer to section 3.4. Seventy Four percent of children were classified as 'normal weight' and 26% as 'overweight/obese' category.

### 4.2.5 Statistical Analysis

Firstly, Q-Q plots and the kurtosis and skewness values for each variable were assessed to identify whether each variable was normally

distributed. The values for skewness and kurtosis were all between <1 and >-1 and therefore normally distributed (Kline, 2005), therefore allowing the use of parametric testing.

In order to examine the relationships between BMI and percentage mastery of each FMS, Pearson's product moment correlations were conducted. Any differences in each FMS according to gender, school Year and BMI (normal weight vs overweight/obese) were examined using a series of 8 (FMS) by 2 (gender) by 2 (BMI) by 5 (Year group) multivariate analysis of variance (MANOVA). Bonferroni post hoc pairwise comparisons were employed, where any significant differences were found in the MANOVA, to determine where these differences lay. In this case with eight dependent variables, the Bonferroni correction was $p \leq 0.05/8 = \leq 0.006$. The Statistical Package for Social Sciences (SPSS inc, Version 20) was used for all analysis. In order to examine the relationships between BMI/ BF% and sprint times and jump height, Pearson's product moment correlations were conducted. Statistical significance was set at $p \leq 0.05$.

## 4.3 Results

Table 4.1 indicates that as the children get older, BMI significantly increased ($p < 0.001$). Bonferroni post hoc tests highlighted that Year 6, had a significantly higher BMI compared to Years 2 and 4 ($p < 0.001$; $p = 0.034$), respectively, and that Year 5 had a significantly higher BMI than Year 2 ($p = 0.003$). However, table 4.1 also displays the cut offs for an overweight BMI specific for each Year group. It is highlighted that the mean BMI for each

Year group does not go into the overweight category, suggesting that the majority of children are of normal weight. However, the standard deviation for each Year group does exceed the cut off and this gets bigger as the Year group increases in age suggesting that there is a larger variation of BMI values between the different Year groups.

Table 4.1. Mean (±SD) BMI for each Year group (n=281).

| | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 |
|---|---|---|---|---|---|
| BMI (kg/m$^2$) | 16.3 ± 2.3 | 16.9 ± 2.3 | 17.3 ± 3.2 | 18.4 ± 3.2* | 18.4 ± 3.1* |
| % of overweight/ Obese | 25.4 | 27.2 | 23.4 | 33.9 | 33.3 |
| BMI cut off of overweight | <17.8 | <18.4 | <19.1 | <19.9 | <20.7 |

*significantly higher BMI than some of the younger year groups (Bonferroni post hoc analysis). (BMI (kg/m$^2$) cut off according to Cole et al., 2000)

## 4.3.1 Subjective FMS results

Table 4.2 indicates that for six out of the eight FMS the majority of children were classed as having 'non-mastery'. The category of near mastery holds the highest percentage of children for catch (40.3%) and balance (34%) skills. The category for full mastery, the three locomotor skills; sprint (3.3%), gallop (12.8%) and hop (3.9%) hold the lowest number of children in this section. The least mastered skill was hop with 79.1% of children showing non-mastery of this skill. The highest mastered skill was catch with 37.1% of children demonstrating mastery.

Table 4.2. Percentage of children who are classed as having Mastery, Near Mastery and Non Mastery for all of the eight FMS (n=281).

| Skill | Mastery (%) | Near Mastery (%) | Non Mastery (%) |
| --- | --- | --- | --- |
| Kick | 19.2 | 12.5 | 68.3 |
| Sprint | 3.3 | 32.1 | 64.6 |
| Gallop | 12.8 | 26.1 | 61.1 |
| Hop | 3.9 | 16.9 | 79.1 |
| Balance | 33.5 | 34.2 | 32.4 |
| Throw | 17.9 | 9.9 | 72.3 |
| Catch | 37.1 | 40.3 | 22.7 |
| Jump | 21.7 | 27.8 | 50.5 |
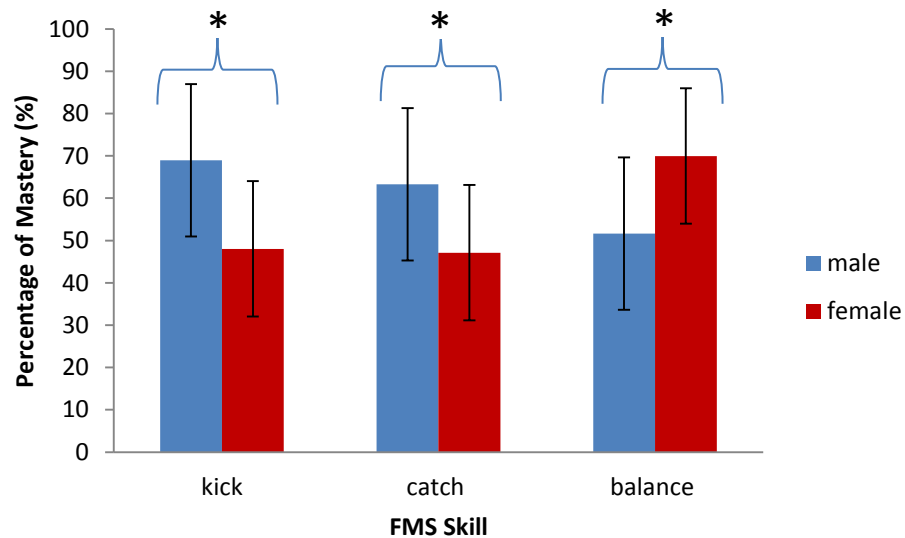
Figure 4.1. Mean (±SD) mastery level in the three trials for the kick, catch and balance that were significantly affected by gender (n=281). *P<0.05 (MANOVA)

Statistical analysis (MANOVA) revealed no significant interactions between FMS, gender and weight status. There were significant main effects for gender, $F(8,181)=10.488$, p=0.001, Wilks' Lambda = .683. Subsequent analysis of each individual dependent variable indicated that different genders were significantly associated with different performances in kick $F(1,188)=46.576$,p=0.0001; balance, $F(1,188) = 17.258$, p=0.0001; throw, $F(1,188) = 29.692$, p= 0.0001 (See Figure 4.1).

A significant main effect for BMI was reported (MANOVA, $F(8,181) = 2.358$. p=0.02, Wilks' Lambda = .906). Analysis of each individual dependant variable was conducted. Changes in BMI were significantly associated with different performances in the sprint run (MANOVA, $F(1,188)= 9.774$, p=0.002 (Figure 4.2).

A significant main effect for Year group was reported (MANOVA, $F_{(32,181)}= 10.847$, $p=0.0001$, Wilks' Lambda = .214). Analysis of each individual dependent variable was conducted. From the MANOVA statistical test different year group was significantly associated with different performance of the jump, $F_{(5,188)} = 24.782$, $p<0.0001$; sprint run, $F_{(5,188)} = 7.802$, $p<0.0001$; gallop, $F_{(5,188)} = 17.214$; $p<0.0001$; hop $F_{(5,188)} = 32.681$, $p<0.0001$; balance, $F_{(5,188)} = 8.286$, $p<0.0001$; throw, $F_{(5,188)} = 8.762$, $p<0.001$; catch, $F_{(5,188)} = 17.521$, $p<0.0001$. Subsequent Bonferroni post hoc tests identify that it is boys that are significantly better at the kick and throw compared to girls and that girls are significantly better at balancing compared to boys. A change in BMI status to overweight/obese had a significant negative effect on mastery of the sprint run (Bonferroni post hoc; $p=0.025$) (See Figure 4.2).
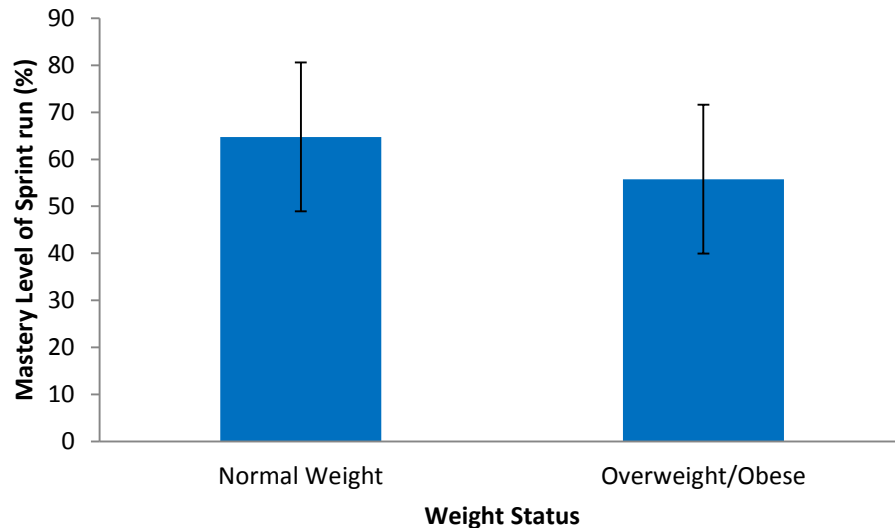
Figure 4.2. Different categories of weight status (normal weight and overweight/obese) were significantly associated with different Mean (±SD) values of mastery level for the sprint run. There was a significant difference between normal and overweight/obese children (Bonferroni post hoc; p=0.025) (n=281).

In Year 4 (mean age 8.42 years old), there was a consistent significantly lower score, than the preceding year group, in mastery level in all three locomotor skills (sprint run, side gallop and the jump) (See Figure 4.3a). In Year 5, (mean age 9.43 years old) there was a consistent lower score, than the preceding year group, in mastery level in all three object control skills (kick, catch and throw) (See Figure 4.3b), however only the catch and throw were significant, the kick was not.

a)
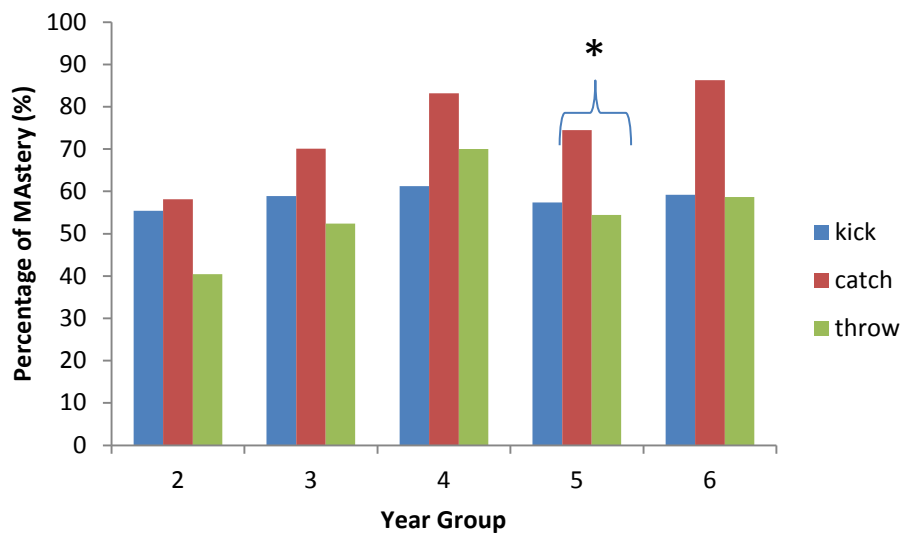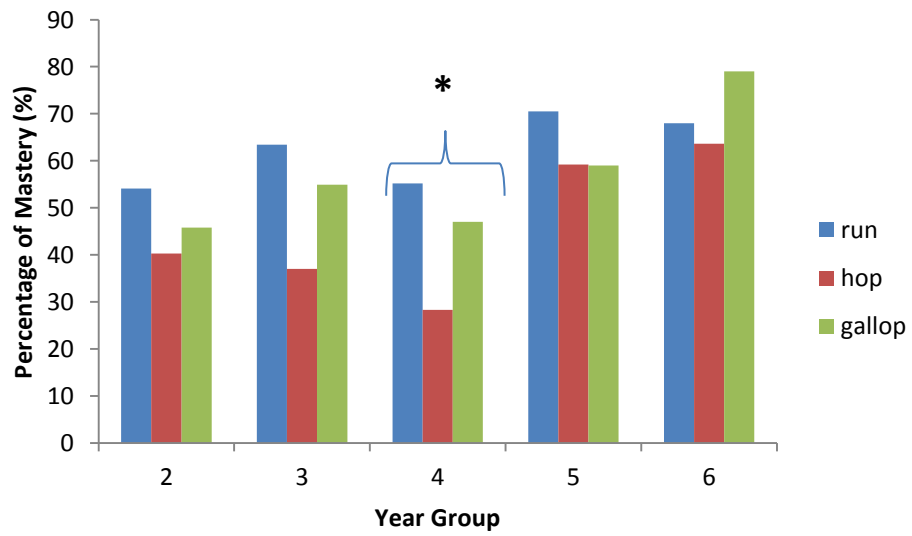


b)



Figure 4.3. Mean mastery level in the three trials for the a) run, hop and gallop and b) kick, catch and throw for each Year group. * Mastery is significantly lower than previous Year group (Bonferroni post hoc; p<0.05) (n=281).

### 4.3.2 Objective FMS results

Bivariate correlations were completed on the participant's best sprint times with the percentage mastery level of the sprint and BMI. There was no significant correlation between sprint time and BMI ($p>0.05$). Normal weight children had significantly faster sprint times compared to overweight children when weight status was determined by BMI (Bonferroni post hoc; $p=0.05$).

A significant correlation was highlighted between sprint time and percentage mastery level of the sprint (Pearson product, $p<0.001$). Figure 4.4 displays that as mastery level of the sprint decreases the sprint time is slower.
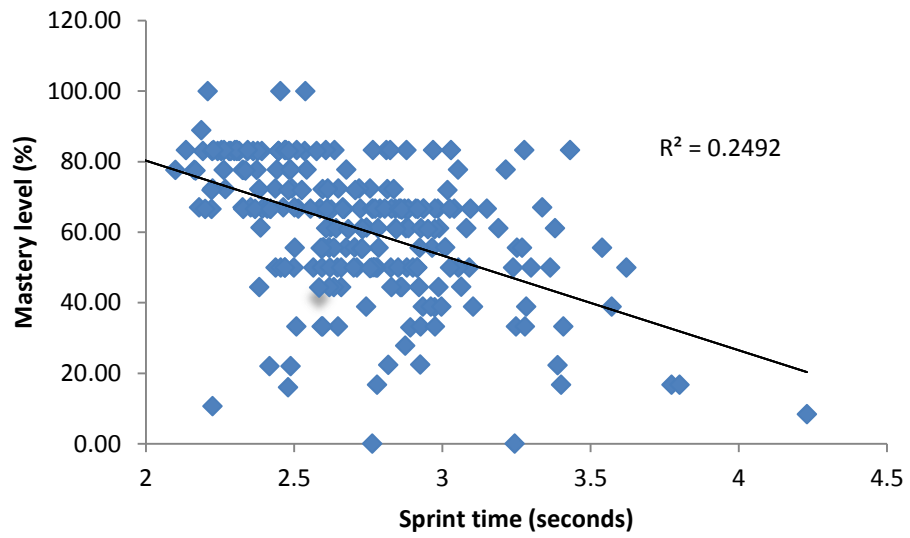
Figure 4.4. Significant correlation between mean mastery level in the three trials of the run and sprint times of all the participants (Pearson product; $p < 0.001$; $r = -0.499$ $n = 281$).
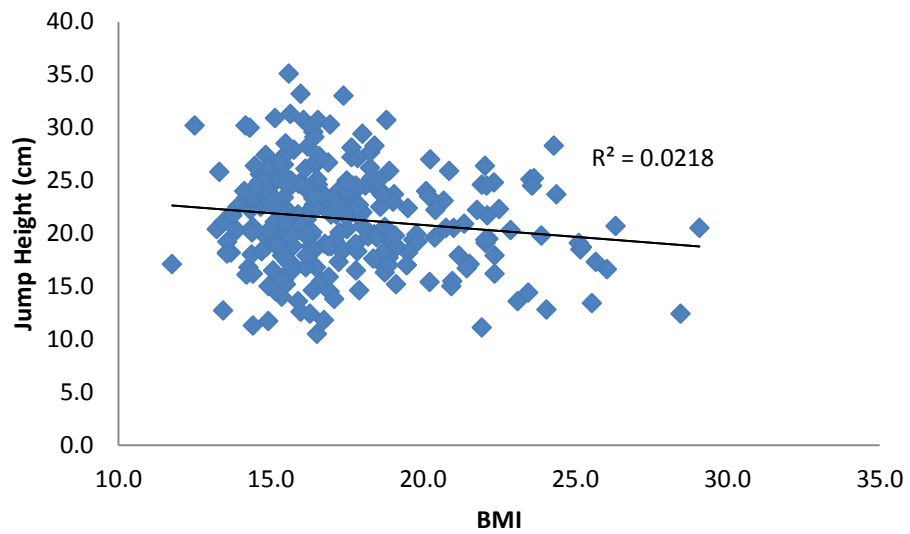
Figure 4.5. Significant correlation between BMI and jump height (Pearson product; p=0.014; r=-0.151; n=281).

A significant negative correlation was highlighted between BMI and the height of the jump (Pearson product; p=0.0,1 r=-0.141). Figure 4.5 displays that the larger the BMI the smaller the jump height. Although the p value suggests this is significant, the r value indicates that the correlation is very weak and figure 4.5 highlights that a child with a jump height of 17cm could have a BMI ranging from 12-26kg/m$^2$.

A significant correlation was highlighted between jump height and percentage mastery level of the jump (Pearson product; p=0.01, r=0.329). Figure 4.6 displays the higher mastery level of the jump the higher the child could jump. Again, this correlation is weak and figure 4.6 suggests that a child who can jump 23cm could have between 0 and 100% mastery of the jump.
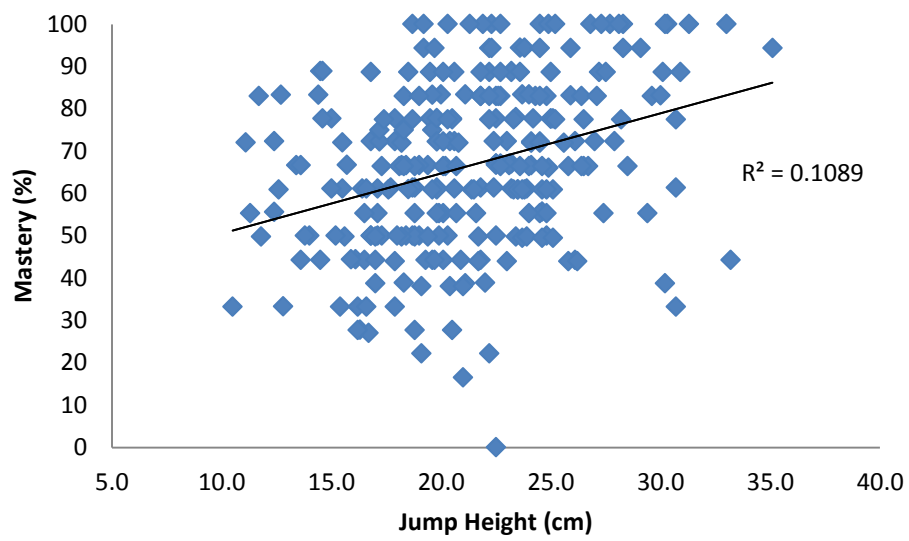
Figure 4.6. Significant correlation between the mean mastery of three trials of the Jump and Jump height of all the participants (Pearson product; p=0.01 r=0.329; n=281).

## 4.4 Discussion

The aim of this study was to examine the relationship between FMS and BMI in a sample of British primary school children taking account year group and gender differences. The results of this study suggest that BMI has a negative effect on the skill level of the sprint run. Year group and gender also have an effect on the mastery of FMS. A decrease in the subjective measure of the sprint run and jump showed a negative impact on objective outcome of these skills (sprint speed and jump height). In addition, if children were classified as being overweight/obese then their sprint speed and jump height were negatively affected.

## 4.4.1 BMI

The present study has demonstrated that the skill most associated with BMI is one that involves moving the whole body mass, i.e. the sprint run. This is consistent with Jones et al., (2010); Lopes et al., (2012) and Okely et al., (2004). Okely et al., (2004) explain that overweight children are more likely to perform poorer in the sprint due to the fact it is a locomotor skill and therefore requires a larger overall body mass movement. This also offers an explanation for the need of an objective measure of the sprint run. In the present study, the subjective technique and objective performance measure of the skill is also assessed. As stated in the method (Section 3.3.1), each skill is made up of five or six components that the children have to display to have mastery of that skill. With the sprint run, it contains components that will

be harder to display with a larger BMI. For example, when a child has a larger BMI, it is likely that there will be a larger amount of adipose tissue present. This would therefore make it physically more difficult for that child to complete certain criterion of the skill, such as 'Non-support foot bent at least $90^o$ in recovery'. Having a larger BMI not only makes the leg heavier to lift up to this angle, but an increase in adiposity around the joint will restrict it to only obtaining certain angles. Therefore, it is harder for the obese child to perform that criterion and in turn decreases the mastery of that skill. By reporting that BMI has a negative effect on a locomotor skill, this highlights a target area for children who are overweight/obese.

## 4.4.2 Age

The novel finding from this research is the low scores in specific skills at different ages. Hands (2008) suggests that there should be a graded response between FMS and age, for example, as the children get older their FMS level should also improve. Hands (2008) reports a longitudinal study on the same children over five years to identify a trend and therefore increasing reliability of the results. In Hands' (2008) study the skills were tested objectively. This risks measuring the maturation stage of the child rather than the technique and developmental level of the skill. For example, if a child is an early maturer and is taller/stronger than their peers then they will be able to throw further or run faster. This will rank the children rather than identify if they can perform the skill correctly irrespective of the maturation status. Although there are some explanations later on in this discussion as to why

this ungraded response has been shown, these results are important to the research aim; to identify key strategies to target interventions to increase FMS and in turn encourage PA participation to maintain a healthy weight status. One explanation as to why this present study does not show this graded response, could potentially be due to there being little consistency in what the school focuses on in PE lessons across different school years. Inconsistency in PE lessons in primary schools is often due to a lack of specialist PE teachers for these year groups. Mitchell et al., (2011) reported that out of 900 teachers, only 11 of them had PE degrees and only 74 had training in PE, thus offering an explanation as to why FMS competency is consistently low and inconsistent between year groups in primary school settings. In the school used for this study, they had one PE specialist who had limited time with each year group and their class teacher was their main PE teacher. Moreover, the children will experience a different teacher each time they progress up a year. In addition to a lack of specialist PE teachers in primary schools, an inspection of Primary schools in the UK by Ofsted (2013) has suggested that there are only a few schools with adapted PE programmes to suit the individual needs of obese pupils, for example, simpler exercises to reduce failure and maintain motivation. This was not included in PE at the school in this study. With the lack of trained PE teachers and specialist PE programmes, the content and method of teaching style in PE could differ across the year groups. Therefore, results from this study would provide a template for potential areas of focus or intervention within a primary school PE curriculum to increase skill level of the children and in turn increase their ability to partake in other PA.

An additional suggestion which may explain some of the changes reported in this study relates to neuromuscular development in children. When reaching Year 3, a child is 7-8 years old and this is when myelination of the axon begins to become apparent (Lenroot and Giedd, 2006). When an axon is unmyelinated an impulse must use an action potential to open the voltage gated sodium channels to reach the nerve and deliver the message. Each of these voltage gated sodium channels are set 2μm apart and therefore this process can be very slow (Guiliodori and DiCarlo, 2004). When the axon is surrounded by the myelin sheath, the voltage gated sodium channels are skipped and the impulse is delivered to its destination much quicker. Moreover, this myelination will cause children to have better motor coordination as the messages from the brain, regarding what to do, will reach the muscles much quicker. However, children develop at different rates and this will occur sooner in some children compared to others, therefore, possibly explaining why in Years 4 and 5 there is considerable variability in the mastery levels of the skills at these ages.

### 4.4.3 Gender

Three of the object control skills were significantly associated with gender; boys performed the kick and catch better and girls displayed a higher mastery of the balance. Jones et al., (2010) supports the current study in that boys outperformed girls in the throw and catch (kick was not assessed), however the authors did not report if this difference was significant as they were not interested in gender but in weight status and

parents perceptions of physical competence. In addition, Hardy et al., (2011) reported that boys were significantly better at performing the kick and the throw ($p < 0.05$) and that boys also outperformed girls at the catch; however, this was not significant. According to Okely et al., (2001), boys are more likely to engage in organised PA and utilise the space given to them, thereby pushing the girls to the outskirts of the space, enabling boys to play and enhance their FMS ability. Okely et al., (2001) explains that it is deemed more socially acceptable for boys to partake in organised PA compared to girls. Girls' FMS ability benefited further from more time in organised PA and therefore suggested that an organised PE intervention would have greatest positive effects on girls (Okely et al., 2001).

Previous research supports the findings represented in the present study that girls outperformed boys in balance and the jump (Okely and Booth, 2004; Vandaele et al., 2011). Neither of these aforementioned studies reports this difference as being significant, unlike the current research. Okely and Booth's (2004) and Vandaele et al's (2011) research both reported that boys significantly outperformed girls in object control skills (kick, throw and catch). This is consistent with this present study. The current study's results suggest that the skills are affected by gender; Blatchford et al., (2003) suggests this is because boys are more likely to engage in ball games compared to girls and thus increase mastery of the object control skills. Girls are more likely to engage in creative games and activities such as gymnastics and therefore excel in skills such as balance and the jump. At primary school age, the children are predominantly in a pre-pubertal maturational stage and should be biologically (somatically) similar (Thomas

and French, 1985; Malina et al., 2004). It can be concluded that these differences are down to the fact that children are socialised into specific types of activities, whether it's free play or organised PA, based upon their gender (Blakemore and Renee, 2005). Poulin-Dubios et al., (2002) conducted a study to identify the age at which children can identify gender stereotypical activities. The results identified that by the age of 24 months children had knowledge of gender stereotyped activities such as shaving and putting make up on. This knowledge of gender stereotyped activity from a young age will be reflected in sporting activities, resulting in differences in mastery level of skills between boys and girls. This gives a justification as to why these gender traits are then reflected in a child's PA and their development rate of mastering FMS.

Results from the current study have identified that boys have a higher mastery of the sprint run compared to girls at every age group, but this difference was not significant. It was reported that boys have a significantly faster sprint time compared to girls. Although the boy's technique of the sprint is not significantly better they can still run significantly faster. These findings suggest that it is somatical compared to environmental external factors that cause the observed difference in the present study. It has already been stated that children are biologically the same at primary school age. Studies have reported that boys take a significantly higher amount of pedometer step counts (Ziviani et al., 2009) and have significantly higher levels of PA participation (Baranowski et al., 1993) compared to girls. When children possess a higher energy expenditure they are more likely to have a healthy weight reflected by a BMI, which increases the muscle power: body

mass ratio of their muscles (Maffeis and Castellani, 2007). If more of a child's body mass consists of muscle mass used to power movement then they should be able to run faster as higher muscle power output per kg of body mass is produced. When locomotor skeletal muscle mass and muscle efficiency is increased this will in turn increase sprint time (Weyand et al., 2000). It can be concluded that muscle mass may explain the gender differences in sprint time performance (Gomez et al., 2008).

Identifying that boys and girls excel at different skills is also important for potential strategies for targeting boys and girls separately to increase mastery in FMS. Additionally, future research into which skills would benefit from being mastered to maximise PA participation and maintain a healthy weight status, could also reflect gender specificity.

## 4.4.4 Object control and locomotor skills

The present study's results support Vandaele et al., (2011) who also reported that locomotor skills are under mastered compared to the other FMS. Westerndorp et al., (2011) suggests that locomotor skills are underdeveloped because they involve moving the whole body and having to simultaneously coordinate the left and right side with top and bottom of the body; therefore making the skill much harder to master. In addition, Westerndorp et al., (2011) states that object control skills generally have a higher mastery level because children tend to prefer ball games. This will enhance object control skills to a higher extent then locomotor skills, which therefore offers an explanation as to why the locomotor skills are under

developed compared to the other skills in the current study. Furthermore, the criteria used to assess the sprint run breaks the skill down to a very technically good professional sprint (Human Kinetics, 2008). This 'good professional' sprint is not practiced or often taught to children. Children learn to walk and progress to running but are never taught the technique to run correctly. When children play games in the playground or even join a sports club, the 'sprint run' assessed in all studies using this method, will not mimic the run they perform in play or in their sport and therefore mastery level will be a lot lower. Regardless of whether this lack of mastery in locomotor skills in children is due to a larger BMI or because they are harder skills to master, it is still important as it highlights the potential skills to be targeted for a PA intervention. However, it is unknown which skills out of the eight FMS are the most associated with engagement in PA. This would be one direction to develop this research further.

### 4.4.5 Objective versus subjective measurement

Results from the present study highlight a significant linear relationship between mastery level of the sprint run/jump and the sprint speed/jump height, respectively. The objective measurement of the skill is associated with the technique of the skill that is executed. Comparing objective and subjective measurements is novel; these results are unique and cannot be compared. Some may argue that the FMS should be measured objectively to show how good they are at performing the skill, i.e. how far the child can throw a ball. However, the results from this study have

indicated that the mastery of the subjective measurement (i.e. the technique) is needed for better objective measurement readings. In addition, if the children were solely tested objectively then they would be ranked and could not be classified as having mastery of that skill and it would be more heavily influenced by the maturation of the child.

Although the correlations between the subjective and objective measurement of the sprint run and the jump were highlighted as significant according to the p value, the r values only showed a medium effect; r=-0.499 and r= 0.329, respectively (Field, 2013). Furthermore, when looking at the $r^2$ values the percentage of shared variance was 24 and 32% for the sprint run and jump, respectively, highlighting that there are potentially other confounding variables that will affect measures of both the sprint run and jump. Therefore, the p value should be interpreted with care with the consideration of the other statistics provided before overall assumptions can be made regarding the relationship between the two variables.

### 4.4.6 Limitations

Despite identifying important information regarding the FMS development of British primary school children, this study does have some limitations. Firstly, the study was limited by the cross-sectional nature of the design. The unique finding from this research is the difference in skill level between the different ages; Year 4 (age 8-9 years) had a lower score in locomotor skills and year 5 (age 9-10 years) had a lower score in object

control skills. Due to this being cross sectional data these low FMS scores in these year groups are likely to be an anomaly or down to the teaching that these year groups have received.

The sample in this study was analysed by year group, however if longitudinal data was collected, results would have been able to highlight how FMS changes as children progress through the year groups in primary school. Also, by categorising the children in to year groups it assumes that all the children are the same age, when in fact there could be up to twelve months difference between two children in the same year group. In conclusion, further research in this thesis will control for this limitation.

Only one school in the Coventry area participated in the research restricting the generalisation of the results to the wider primary school population. Although this does provide a snapshot of the FMS of UK children in the primary school system, the PE system in secondary education in the UK revolves around specialist PE teachers. It would therefore be of interest to examine what effect (if any) the exposure to specialist PE teaching might have on FMS in children. This is a direction for further research. Furthermore, assessing FMS levels in primary schools with specialised PE teachers could potentially highlight areas of discrepancies between primary school teachers. However, differences may have an association with SES.

In addition, BMI was used in this study to categorise weight status. This holds its own limitations as BMI cannot distinguish between body fat and fat free mass (Nevill et al., 2006). Therefore, if further research in children wishes to assess the effect that obesity has on performance of FMS,

researchers may be better placed employing a measure of body fatness (e.g., via use of skinfold callipers) rather than a measure of weight status using BMI.

Age and sex specific cut offs were used to determine the children into weight categories (overweight/obese and normal weight). The sample size for the obese children was too small to have its own weight category, thus why overweight and obese were grouped together. This caused children who may have just been in the 85th percentile to be grouped with children who were over the 95th percentile. The future studies in the thesis will use z scores to identify how far away the children are from being a normal weight to give a better understanding of their weight status.

The final limitation of this study is that it was only possible to assess the jump and sprint objectively and subjectively to analyse if there was an association between the two methods of analysis. Although, it would be good to have objective data for all eight FMS, it was not the primary aim of the study. Previous research has identified that it is the technique of the skill that is associated with PA levels and a lower weight status (Okely et al., 2001; Graf et al., 2004; Okley et al., 2004 and Barnett et al., 2008), therefore justifying the main use of the subjective measure.

### 4.4.7 Future research

Given the premise that FMS may actually reduce the number of children categorised as overweight and obese, because better mastery of FMS is more likely to increase habitual PA, it is perhaps crucial that researchers investigate whether FMS is predictive of later PA. It would be interesting for future research to track children's FMS level through a longitudinal study to highlight if previous or current FMS is predictive of future PA level.

### 4.4.8 Conclusion

This information in the study is important in understanding how age, gender and weight status can be associated with the development of FMS as the children progress through the primary school. These findings may provide useful information for targeting interventions or enhancing PE policy. Although PE in primary schools has many different aims and objectives to teach the children, the results from this study should be used to advocate that the teaching of FMS should be included as an area of focus for any future school PE curricula.

The unique and novel finding from this research is the difference in skill level between the different ages; Year 4 (age 8-9 years) had a lower score in locomotor skills and year 5 (age 9-10 years) had a lower score in object control skills. This is particularly interesting as it highlights critical ages at which interventions need to be targeted to encourage an uptake in PA to

allow the children to maintain and develop their FMS level, to maintain a healthy PA level and weight status (BMI). [1]

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[1] The data from this chapter are published as follows: **Bryant, E.,** Duncan, M., and Birch, S. (2013) Fundamental Movement Skills and Weight Status in British Primary School Children. *European Journal of Sports Science*, 14 (7):730-736 DOI:10.1080/17461391.2013.870232

## 5.0 Is current FMS a predictor of current or future PA levels and weight status in British primary school children?

### 5.1 Introduction

Higher levels of PA are related to multiple positive health outcomes in children and adults (Li and Siegrist, 2012; Erkisen et al., 2013). PA levels have been tracked from childhood to adolescence (Kelder, et al., 1994) and from adolescence into adulthood (Kjonniksen et al., 2008). Children who do not participate in the recommended guidelines for PA (60 minutes of MVPA per day) are much less likely (r=0.57) to be active teens and adults (Malina, 2001). Recently only 32% of boys and 24% of girls aged 2-15 years old met these recommended guidelines in Great Britain (British Heart Foundation, 2012). In addition to obesity, other cardiovascular disease risk factors such as hypertension and high cholesterol have been tracked throughout life from a young age and are linked to low PA (Wilkinson et al., 2011). Therefore, it is important to target children as a preventive measure against later life disease related to physical inactivity and obesity.

In order to address these issues of the small amount of children meeting the PA guidelines and increasing obesity, the assessment and development of FMS in childhood have been examined (Mckenzie et al., 2002; Okely and Booth, 2004; Barnett et al., 2008; Bryant et al., 2013). By having mastery of the FMS this will enable children to successfully partake in PA, increase motivation and maintain an increased PA level (Gallahue and Ozmun, 2002, Barnett et al., 2008, Stodden et al., 2008).Therefore, it is

important to better understand the relationship between FMS mastery and PA for potential interventions. A review by Lubans et al., (2010) highlighted five studies that elucidated that a larger weight status is negatively associated with FMS mastery (Graf et al., 2004; Okley et al., 2004; Southall et al., 2004; Cliff et al., 2009; Erwin and Castelli, 2008; D'Hondt, et al., 2009). However, for all five of these studies, BMI was used to determine weight status. The main limitation when BMI is used in children is the assumption of a linear BMI-body fat relationship which does not hold in paediatric populations. Additionally, the processes of growth and maturation influence the accuracy of BMI as a proxy for body fatness in children (Jackson et al., 2002). Therefore, when BMI is analysed in children, results should be interpreted with care (Cole et al., 2000). There are alternative methods available for assessing weight status, such as measuring body composition (fat mass), which avoids the limitations of BMI. As children mature at different rates, previous research has identified that it is more useful to measure body composition than to use BMI (Doak et al., 2013).

Research has highlighted that there is an association between higher FMS levels and higher PA levels in children and adolescents (Okely et al., 2001; Vandorpe et al., 2012). Okley et al., (2001) reported that children who were classed as having 'very high' movement skill proficiency spent significantly ($p<0.05$) more time in organised PA (68% and 35% higher in girls and boys respectively) and non-organised PA compared to children who were classified as having 'very low' movement skill proficiency. Vandorpe et al., (2012) reported that children who participated in organised PA for three years or more had significantly higher FMS competency compared to the

children who did not participate in any PA. Both Okely et al., (2001) and Vandorpe et al., (2012) used self-reported measures of PA. Although this association between FMS and PA has been highlighted, there are few longitudinal studies that have assessed the relationship between childhood FMS and future PA level (Okley et al., 2001 and Mckenzie et al., 2002; Barnett et al., 2008). Okely et al., (2001) and Barnett et al., (2008) both reported that very small variations in adolescent PA could be predicted from childhood FMS competency.  In contrast to this, Mckenzie et al., (2002) did not identify a relationship between childhood FMS and future PA levels. None of these three studies reassessed FMS competency when they measured the future PA levels. This is important because by not measuring current FMS, it is not known whether children need to gain FMS mastery in order to participate and maintain participation in PA, or whether an increase in PA participation will develop and increase mastery of FMS (Graff et al., 2004 and Hume et al., 2008).

Bryant et al., (2013) also reported a negative relationship between a higher BMI and low FMS performance. In addition it was identified that children in higher year groups do not progressively increase in FMS mastery in the manner that other research would suggest (Hands et al., 2008). By highlighting these dips in performance of certain skills between year groups, Bryant et al., (2013) suggested that some skills could potentially be more important in influencing PA participation than others.

This present study aims to highlight the skills most important in predicting PA. In addition it will build on prior work and offer further insight into understanding this relationship between FMS and PA to better enable a

targeted intervention. Such information is also needed to inform PE practice and health policy in the UK.

Based on the findings of the previous study (study 1) which found that children in England lacked mastery of FMS and that FMS was negatively associated with a higher weight status, the present study will explore if FMS is significantly associated with PA levels.

The objective of this study was be to predict the variance in PA (average daily steps) at time point two from the FMS measured at time point one and two. The aim of this study was to identify whether FMS measured one year previous or FMS measured at the same time point or a combination of the two is a better predictor of habitual PA levels in children. This study is novel as it will assess FMS at two time points to identify which time point can best predict variation in PA, which other studies have failed to do (Okley et al., 2001 and Mckenzie et al., 2002; Graf et al., 2004; Barnett et al., 2008; Hume et al., 2008). This study will also measure body composition (BF%) to overcome the previous problems of using BMI. The hypothesis below is based on Stodden et al's (2008) theoretical model, as it suggests that PA is a direct consequence of motor competence (FMS level).

### 5.1.1 Hypothesis

*Experimental hypothesis:* Mastery of FMS will predict habitual PA levels. Current FMS mastery level will be a better predictor of current PA and weight status compared with previous FMS mastery level.

**5.2 Method**

**5.2.1Sample**

Following Coventry University ethical consent the present study began in January 2012 (year one). A sample of 292 children was recruited from one primary school in Coventry. Informed consent from parents/guardians was gained from 281 children (129 boys, 152 girls) who then participated in the study. Year groups 2-6 (age 6-11 years) were assessed with an overall mean (±SD) age of 8.9 years (± 1.4 years). From the sample, 84% of the children were White British, 15% were Asian and1% was Afro-Caribbean, this is a representative sample of the ethnic diversity for the West Midlands (Coventry City Council, 2013). The City Council's Lead advisory teacher for PE assisted in the selection of the chosen school. The school that was chosen sat in the mid-range (50-59%) of electoral wards for deprivation and socio-economic status within the city and nationally (Coventry City Council, Key Statistics, 2012) as a means to ensure the extremes of affluence and deprivation did not confound the results of the study. Between the two years of testing, children had their scheduled PE lessons but had not received any additional PA/PE programmes during or between testing periods.

The data collection was repeated one year later (2013, year two) in either the same primary school or the secondary school that individual children had moved to. Informed consent was gained from the children's parents/guardians for this phase of the research. Due to families moving away or children going to different secondary schools the sample for the

longitudinal phase of the study was 252 (116 boys and 136 girls) children (90% follow up rate), with a mean age at year 2 of 9.8 years (± 1.4 years).

## 5.2.2 Anthropometric Measurement

Table 5.1 displays the proportion of normal and overweight/obese children in year 1 (2012) and year 2 (2013) determined by BMI and BF%.

### 5.2.2.1 BMI

Children's body mass and height were measured to calculate BMI to be used to classify weight status. For a full description on how BMI was assessed refer to section 3.4. BMI was calculated as $Kg/m^2$, with the 1990 reference curves controlling for age and sex used to identify overweight and obese children (Cole et al., 1990). Children were classed as overweight if they were in the $85^{th}$ centile and obese if in the $95^{th}$ centile (Cole et al., 1990).

### 5.2.2.2 Body fat percentage (BF%)

BF% was calculated using skinfold assessment from two sites; tricep and medial calf. For a full description on how BF% was assessed refer to section 3.4.Children who fell into the $85^{th}$ centile were classed as overweight and children who fell into the $95^{th}$ centile were obese (McCarthy et al., 2006).

### 5.2.3 Fundamental Movement Skill assessment

#### 5.2.3.1 Subjective Measurement

Children performed eight FMS (run, hop, gallop, kick, catch, throw, balance and the jump). For a full description on how the FMS were assessed refer to section 3.3.1.Prior to analysis inter and intra rater reliability analysis was performed for all the FMS between the two researchers and the lead researcher. Inter rater reliability was conducted in year one and year two producing a score of 90.3% and intra rater reliability was 97.6% demonstrating good reliability (Jones et al., 2010).

#### 5.2.3.2 Objective measurement

The sprint run and jump were both measured objectively for time (sec) and height (m) respectively. For a full description on how the objective measurement of FMS were assessed refer to section 3.3.2.

### 5.2.4 Physical Activity (PA)

PA was assessed using a sealed Yamax Digi-Walker (SW 700) worn over four days (two weekdays and two weekend days). For a full description on how PA data were recorded refer to section 3.6. From these recordings average daily step, average weekend step and average weekday step counts were calculated for the analysis (Table 5.2.)

### 5.2.5 Statistical Analysis

Regression relationships were analysed between all 20 variables and age. For any variables that were significantly related to age, age could be masking the true variation in that variable. 15 out of the 20 variables were significantly related to age and therefore unstandardized age residuals were calculated for those 15 variables. By using the unstandardized age residuals this removed age as a confounding factor, as a new age independent 'score' was assigned to each participant according to whether they were relatively better or worse than the performance that would be predicted, from the regression relationship, for their age.

Once this was completed the Q-Q plot and the kurtosis and skewness values for each variable were assessed to identify whether each variable was normally distributed. For data to be normally distributed the values for skewness and kurtosis had to be between <1 and >-1 (Kline, 2005). There were only two variables that were not normally distributed (kick year 1 and speed year 1). To achieve normality, the kick year 1 and speed year 1 data

sets were transformed. Firstly arcsine transformation was conducted on the two non-normal data sets: $y_1$ = 2×arcsine($\sqrt{y}$) (Black, 1999). Arcsine transformation caused kick 1, but not speed year 1, to become normally distributed. Square root transformation still caused the values for speed 1 to be non-normal, but closer to the desirable kurtosis and skewness values (0.882 and 1.493, respectively). A further consideration of the Q-Q plot identified that speed 1 showed 2 values that were large outliers. These were visually identified by two data points being far away from the normal distribution line on the Q-Q plot. These two participants were removed from the data set. Once these data points were removed the values for kurtosis and skewness became normal. Discriminant function analysis was carried out on the complete data set to identify whether boys and girls were significantly different groups and should therefore be analysed separately. For boys and girls the Wilks' Lambda value was significant (0.514, p<0.001) indicating that boys and girls were significantly different and should be analysed separately. Multiple linear regression analysis, with use of the enter method, was used to assess the multicollinearity of the variables in the data set. The VIF (variable inflation factor) value was checked for each variable. All variables had a VIF <2 which identified that a stepwise multiple linear regression analysis would be an appropriate method to analyse all the data sets simultaneously. Three models were created each with the dependent variable as average daily steps. Independent variables were all eight subjective FMS from year 1 and 2 and the two objective FMS from year 1 and 2. BF% from year 1 and 2 were controlled for as a potential confounding factor. Model 1 assessed the associations between FMS in 2012 with

average daily steps in 2013; Model 2 assessed the associations between FMS in 2013 and average daily steps in 2013; Model 3 assessed the association between a combination of FMS (in 2012 and 2013) and average daily steps in 2013. The Statistical Package for Social Sciences (SPSS inc, Version 20) was used for all analyses and statistical significance was set at $P \leq 0.05$ a priori.

This study's aim was to examine if and how much FMS could be a predictor of current or future PA levels. Mastery level for each of these FMS could be predicted by the child's age. In such analysis if age was not controlled for then the effects of age would at least partially hide the effects of FMS; so when a value is calculated to suggest how much of a child's PA could be predicted by FMS level, this number would actually be explaining how much a combination of age and FMS contributed to the PA. By removing the effects of age, it more clearly indicates to what extent FMS level is associated with PA. Boys and girls differ in the association between FMS and PA. When boys and girls were analysed together lower levels of PA were predicted because the association between FMS and PA in boys masked the association (FMS and PA) in girls and vice versa. The data was analysed as two separate groups, identifying the skills that are important in predicting PA for boys and girls separately.

Analysis of variance (ANOVA) was conducted the in the BF% and BMI data to identify if children had increased significantly from year 1 to year 2. An ANOVA with bonferroni post hoc analysis was conducted on the pedometer steps counts to identify differences between gender and weekend and weekday steps.

## 5.3 Results

Table 5.1 demonstrates the number of children that were classified as normal weight and overweight/obese over the two years of assessment according to BMI and BF%. Following the AVOVA children did not significantly increase BMI or BF% (p>0.05).

Table 5.1. Mean (±SD) BMI and BF values, and percentage of normal and overweight/obese children, in year 1 (2012) and year 2 (2013) determined by 85th and 95th centiles according to Cole et al., (1990) for BMI and McCarthy et al., (2006) (n=252).

|  | Normal weight (%) | Overweight/obese (%) | Mean (±SD) |
|---|---|---|---|
| **BMI** |  |  |  |
| **Year 1** | 70 | 30 | 17.5 (2.9) |
| **Year 2** | 69 | 31 | 17.7 (3.4) |
| **BF%** |  |  |  |
| **Year 1** | 78 | 22 | 14.6 (2.9) |
| **Year 2** | 60 | 40 | 21.9 (8.5) |

Table 5.2 demonstrates that boys are significantly more active than girls (Bonferrino post hoc; p=0.003) and that both boys are more active on weekdays compared to weekend days (Bonferrino post hoc; p=0.001)

Table 5.2. Mean (±SD) step counts for average daily, weekend and weekday habitual PA (n=252).

| Gender | Daily Steps | Weekend steps | Weekday steps |
|---|---|---|---|
| **Combined** | 8820 (3724) | 8005 (4316) | 9603(4053) |
| **Boys** | 9712 (3816) | 8819 (4427) | 10514 (4236) |
| **Girls** | 8064 (3488) | 7314 (4116) | 8830 (3741) |

The term variance is used to indicate that when a certain variable is measured the value gained differs between children. There are many different factors that could contribute to the level of PA performed by each child (for example, SES, gender, parents, media, peers, diet, FMS), such that any of these variables could be associated with significant variance in the quantity of PA. When the term variance is used in the results section it is explaining how much, as a percentage, the differences between children in FMS score can contribute to the differences between children in PA, suggesting that the rest of variance in PA level is caused by other variables. Tables 5.3a and 5.3b report the individual skills that significantly predict PA and how much of the PA can be predicted, which is reported as a percentage of the variance.

Below are the results for boys and girls when controlled for age via the use of age independent scores as appropriate. This was explained in section 5.2.5.

### 5.3.1 Associations between prior FMS and PA (Model 1)

The girls' jump height and hop combined predicted 26.5% of the variance in PA (average daily steps; Table 5.3a). For boys', sprint speed predicted 15.5% of the variance in PA (Table 5.3b).

### 5.3.2 Associations between current FMS and PA (Model 2)

The girls' hop predicted 11.6%% of the variance in PA (Table 5.3a). For boys', sprint speed predicted 7.1% of the variance in PA (Table 5.3b).

### 5.3.3 Associations between a combination of prior and current FMS and PA (Model 3)

A combination of the girls' hop ii, hop i and gallop ii predicted 34.9% of the variance in PA (Table 5.3a). For boys', sprint speed i predicted 16.3% of the variance in PA (Table 5.3b).

### 5.3.4 Associations of all three models for girls and boys combined.

When the boys and girls data were combined and the regression analysis was combined it did not produced as high a percentage of variance in PA compared to when boys and girls data were analysed separately (model 1, 12.4; model 2, 12.1; model 3, 14.9) (Table 5.3c).

Table 5.3a Multiple linear regression analysis for PA (average daily steps) from FMS scores in 2012 and 2013 for girls.

| Model no/Predictor Variable | β † | 95% CI‡ | P- vale | % variance |
|---|---|---|---|---|
| **Model 1** | | | | |
| Jump height i (cm) | 3452 | 1333, 5572 | 0.002 | 17.6 |
| Hop i (%) | 3178 | 1843, 5513 | 0.008 | 26.5 |
| **Model 2** | | | | |
| Hop ii (%) | 2564 | 1957,4170 | 0.002 | 11.6 |
| **Model 3** | | | | |
| Hop ii (%) | 2517 | 1940, 4120 | 0.032 | 14.2 |
| Hop i (%) | 3898 | 1780, 6016 | 0.001 | 29.0 |
| Gallop ii (%) | 2220 | 1176, 4323 | 0.039 | 34.9 |

Model 1 – associations between FMS in 2012 with average daily steps in 2013; Model 2 – associations between FMS in 2013 and average daily steps in 2013; Model 3 – association between a combination of FMS (in 2012 and 2013) and average daily steps in 2013; β † = unstandardized beta coefficient;  95% CI‡ - upper and lower limit 95% confidence intervals; i = skill from 2012 ; ii = skill from 2013.

Table 5.3b Multiple linear regression analysis for PA (average daily steps) from FMS scores in 2012 and 2013 for boys.

| Model no/Predictor Variable | β † | 95% CI‡ | P- vale | % variance |
|---|---|---|---|---|
| **Model 1** | | | | |
| Sprint Speed i (sec) | -11698 | -19067, -4329 | 0.002 | 15.5 |
| **Model 2** | | | | |
| Sprint Speed ii (Sec) | -5185 | -9544, -1827 | 0.02 | 7.1 |
| **Model 3** | | | | |
| Sprint Speed i (sec) | -11107 | -18192, -4022 | 0.03 | 16.3 |

Model 1 – associations between FMS in 2012 with average daily steps in 2013; Model 2 – associations between FMS in 2013 and average daily steps in 2013; Model 3 – association between a combination of FMS (in 2012 and 2013) and average daily steps in 2013; β † = unstandardized beta coefficient;  95% CI‡ - upper and lower limit 95% confidence intervals; i = skill from 2012 ; ii = skill from 2013.

Table 5.3c Multiple linear regression analysis for PA (average daily steps) from FMS scores in 2012 and 2013 for girls and boys combined.

| Model no/Predictor Variable | β † | 95% CI‡ | P- vale | % variance |
|---|---|---|---|---|
| **Model 1** | | | | |
| Sprint Speed i (sec) | -6672 | -12073,-1270 | 0.016 | 9.4 |
| Run i (%) | 2095 | 1058,4131 | 0.044 | 12.4 |
| **Model 2** | | | | |
| Sprint Speed ii (Sec) | -4743 | -7182, -2304 | 0.001 | 7.9 |
| Balance ii (%) | 1606 | 437, 2776 | 0.007 | 12.1 |
| **Model 3** | | | | |
| Sprint Speed i (sec) | -6836 | -11694, -1978 | 0.006 | 10.7 |
| Kick i (%) | 1619 | 202, 3037 | 0.026 | 14.9 |

Model 1 – associations between FMS in 2012 with average daily steps in 2013; Model 2 – associations between FMS in 2013 and average daily steps in 2013; Model 3 – association between a combination of FMS (in 2012 and 2013) and average daily steps in 2013; β † = unstandardized beta coefficient;  95% CI‡ - upper and lower limit 95% confidence intervals; i = skill from 2012 ; ii = skill from 2013.

## 5.4 Discussion

Prior research has assessed previous FMS as a predictor of future PA level (Okley et al., 2001 and Mckenzie et al., 2002; Barnett et al., 2008). By not reassessing FMS when PA was assessed in a follow up, it was not possible to identify whether the association between prior FMS and PA was more or less than the association between current FMS and PA. Therefore, the purpose of this study was to identify whether previous or current FMS level could predict PA levels. The results highlighted that both prior and current FMS can independently predict PA levels. However, a combination of prior and current FMS predicted the highest amount of variance in PA one year later in boys (16.3%) and girls (34.9%).

For BMI, average values stayed the same from one year to the next, with approximately 70% of children being classed as normal weight and 30% of children as overweight or obese. According to the Health and Social Care Information Centre, Lifestyles Statistics (2013) reports that 29.5% of children are overweight or obese, making the present study's sample representative of children in England.

In the present study, although variance in current or prior FMS is associated with the variance in current PA levels, it was a combination of current and prior FMS that had the highest association with PA in year 2. Barnett et al., (2008) and Vandorpe et al., (2011) have both reported associations between childhood FMS and adolescent PA levels. Both studies conclude that mastery in childhood FMS is important for the children to be physically active in later life. The authors should not conclude this explicitly

as they did not assess FMS and PA at both time points. To fully understand if childhood FMS does increase future PA levels both variables would have to be measured at two time points to identify if the children without mastery of FMS did increase in PA or not. This is also a limitation of the current research and because of this just the association between FMS and PA can be reported. Although the results of the current research support Barnett et al., (2008) and Vandorpe et al's (2011) findings, the current research builds on them to suggest that both previous and current FMS mastery are associated with PA levels. This is supported by Stodden et al's (2008) conceptual model that explains that motor coordination forms the basis to be physically active to influence weight status, which feeds back into motor coordination. This model suggests a constant reciprocal relationship that is ongoing as children develop. In contrast to these findings, McKenzie et al's (2002) longitudinal study that assessed FMS at age four years and PA at age 12 years, did not find a relationship between the two. McKenzie et al., (2002) only measured three skills (lateral jumping, balance and catching), therefore not assessing the full set of FMS that have been identified to form the foundations of physical and sporting activities (Burton and Miller 1998). McKenzie et al., (2002) suggest that skills which involve more strength and power are likely to have a stronger association with later life PA. This is supported by the current research as the skills that that were identified as significantly contributing to the predictive models were the sprint run, jump and hop. These three skills require more speed and power compared to the other skills assessed.

It has been reported that children do not show associations between FMS and PA until the age of school entry (McKenzie et al., 2002; Kelly et al., 2006; Hardy et al., 2010) when children have had the exposure to structured PE lessons and access to afterschool clubs. Furthermore, the skills were measured objectively by McKenzie et al., (2002); therefore it could actually be the technique of the skill that is associated with future PA, as reported by Barnett et al., (2008) and Vandorpe et al., (2011). This conclusion needs further research but if this were to be the case then it would highlight whether technique or objective outcomes of skill performance are more important at a young age.

In the current research, previous and current performances of the hop and gallop, predicted the highest proportion of current PA. Hop and gallop are locomotor skills and previous research has highlighted that children have a lower mastery level of locomotor skills when compared to other FMS (Vandaele et al., 2011; Bryant et al., 2013). Locomotor FMS are harder to master than the object control or stability FMS because they involve moving the whole body mass from one point to another whilst simultaneously coordinating all parts and sides of the body to produce the movement (Westerndorp et al., 2011). The hop is one of the harder locomotor FMS to master, due to the shift of body mass onto one leg. This shift not only doubles the weight on that one leg, but decreases the base of support, as a result making it harder for the centre of gravity to stay within the base of support and for the child to remain on balance (Burkett, 2010). The difficulty is further exacerbated by the increased motor control and coordinative factors required to swing the resting leg and arms to aid the movement of the

hop. In theory, if the other FMS are easier to master than the hop, and mastery of the hop is present then children would be more likely to have mastery of the other 'easier' FMS and have the skill set to partake in PA. This is however speculative as to why current hop performance one year prior to PA assessment contributes to the prediction of 34.9% of the variance of PA in girls. Blatchford et al., (2003) suggests that girls are more likely to engage in creative games or PA such as dance and gymnastics, and for these types of activities the coordination and rhythm needed to participate and maintain participation is similar to what is needed to master the hop and gallop, indicating why the mastery of these two skills is so important in girls.

In boys, variation in FMS in year 1 predicted 16.3% of the variation in average weekday steps one year later, with sprint speed significantly contributing to the model. Okely et al., (2001) reported that boys are more likely to participate in organised games in the playground and to utilise the space around them. As a consequence the games participated in will involve a lot more running, suggesting why sprint speed is also very important in boys.

Barnett et al., (2008) reported overall gender differences in FMS but did not analyse them separately when conducting the regression analysis. In the current study, discriminative function analysis identified boys and girls as being significantly different groups and once analysed separately, larger variations were explained for each gender group. For example, FMS in year one predicted 14.9% of variation in average daily steps when boy's and girl's data were combined. When analysed separately, 34.9% and 16.3% of variance in average daily steps was predicted in girls and boys, respectively.

Therefore, prior studies that have analysed the data combining both genders may not be reporting the true variance of FMS in PA (Barnett et al., 2008). When the data were analysed with the boys and girls combined, it was also model 3 (a combination of FMS from year one and two) that predicted the highest percentage of variance in current PA levels, which is consistent when the boys and girls were analysed separately.

When the initial regression analysis was conducted on all 20 variables, 15 were significantly influenced by age. For these 15 independent variables, age could be masking the true variance of the dependent variables. Age residuals were analysed for these 15 variables to ensure that all analyses undertaken in this study considered the effects of FMS independently of the effects of age. Barnett et al., (2008) reported that object control skills can predict 8% of variation in MVPA in adolescents. It was identified that 'grade' (year group) significantly affected the variables measured, by reporting that children in a higher grade had a significantly higher FMS score compared to children from a lower grade. When using school grade, there could be up to 12 months between children from the same 'grade' and therefore this could have been masking the true effect of the object control skills on MVPA. Like the current study if the effect of age had been controlled for, a higher prediction of PA may have been reported. This is important because recent research has identified relative age effects in the performance of some tests of physical performance, including vertical jump, in a non-sport specific population of British children (Sandercock et al., 2013). The statistical analysis employed in the present study controlled for the effect of age. However, future research examining whether there is a

relative age effect in performance of FMS may be of particular interest to teachers and coaches.

The current research, reports that FMS performance is associated with 16.3-34.9% of boy's and girl's PA, respectively. This leaves between 83.7-65.1% of the variance in children's PA unexplained for. There are many other external variables that will contribute to a child's PA level. Sallis et al., (2000) conducted a review on correlates of children's PA from 54 papers. From these papers, 32 variables were highlighted as being significant correlates of PA. These included individual characteristics (Age, gender, BMI, ethnicity, SES), psychological characteristics (perceived competency, self-efficacy, attitude, dislike of PE, PA intention, PA preference, perceived benefits), lifestyle habits (diet, calorie intake, previous PA experience, sedentary time, peer influence, time spent outdoors, access to facilities, season) and parental influences (parental BMI and PA, parent and child PA, transportation to PA, paying of PA fees). Considering all of these variables that have been highlighted to significantly relate to a child's PA level, 16.3% and 34.9% of PA that can be predicted from FMS competency now appears to be a large proportion of the variance. All the results from the papers in Sallis et al's (2000) review were predominantly analysed using correlations, ANOVAs and t tests. It would be interesting to analyse these variables using regression analysis to highlight how much of each variable is associated with PA. Schaben et al., (2006) reported that a combination of parental influence, perceived competence and attraction to PA explained 36% of the variance in childhood PA. Other studies have also reported psychological factors that are predictive of PA and have ranged from 5.5% to 28% (Erguson et al.,

1989; Reynolds et al., 1990; Zakarian et al., 1994; Garcia et al., 1995; Sallis et al., 1999; Raudsepp et al., 2002; Paxton et al., 2004).

In contrast Wilkin et al., (2006) proposed that a child's PA level is centrally controlled from within your body and is not associated with external variables. Wilkin et al., (2006) assessed three primary schools, one of which had nine hours of PE per week whilst the other two had a proximally two hours per week. Results highlighted that children from all three schools had a similar (within 3%) total PA time. Suggesting that the children who had less time spent in PE during the school day, made up for this outside of school. Furthermore, mode of transport to school (driven or walking) and sedentary activities (TV viewing time) did not show a difference in total PA reported between the children. With the possibility that PA is centrally controlled it does not give any evidence as to why PA levels have decreased over years and why children are not meeting the healthy guidelines.

As discussed, Stodden et al's (2008) conceptual model suggests that FMS competency will influence PA which in turn will affect weight status. Metcalf et al., (2011) also reports what may influence PA but suggests that it is in fact the reverse of Stodden et al's (2008) findings. Metcalf et al., (2011) reported that BF% significantly predicted PA but PA did not predict BF%. More specifically children with an additional 10% of BF at age 7 years reported a decrease of 4 minutes of MVPA per day from the age of 7-10 years. Although, weight status may predict PA, measures need to be put in to place to ensure that children maintain a healthy weight status in the first instance. To maintain a healthy weight status children need to have an equal energy balance and one method to achieve this is to be physically active to

counteract any additional energy intake (food). The results from the current research suggest that mastery of FMS is associated with PA. Therefore, if children have mastery of FMS in early childhood (<7 years) this would associate with PA participation and therefore prevent children from a positive energy balance and gaining BF to cause them to become overweight and obese.

Although children in the current study were at a pre-pubertal stage of maturation and somatically the same (Thomas and French 1985; Malina et al., 2004), statistical analysis identified boys and girls as being significantly different when assessing them for FMS. The skills that were significantly different were, boys were better at the kick and catch, whereas girls were better at the balance test and this is consistent with previous research (Okely and Booth, 2004; Vandaele et al., 2011; Bryant et al., 2013). Children are socialised into specific types of activities, whether it's free play or organised PA based upon their gender (Blakemore and Renee, 2005) suggesting why some skills are more important for predicting variation in PA depending on gender. Whilst this identifies the skills that need to be improved for each gender group it also identifies that equal opportunities need to be provided for both genders so that all FMS can be equally learned, practiced and developed.

## 5.5 Limitations

The present study holds limitations; the first being the use of pedometers in children. Pedometers are not able to identify non wear time or

distinguish between intensity and type of activity. To overcome this issue, children were given diaries to record with parents when they did not wear the pedometer and any children who had values <1000 steps or >40,000 steps per day were excluded from the analysis (Rowe et al., 2004). Although identifying the intensity and type of the activities completed would be beneficial, for the present study the measurement of habitual PA was the objective and research has shown pedometery to be a valid tool to obtain this objective.  To overcome these limitations, accelerometers could be used for future research. Unfortunately that was not possible for the research in this thesis. However, if accelerometers were used in this study, information on the association between different skills and intensity of PA could be reported. Also, non-wear time of the device would have been reported and unreliable data could be removed.

Although the limitations of the use of BMI in paediatric populations has been identified, it has been included in the present study to make it comparable to other studies. In addition, BMI is the method recommended, by the International Obesity Task Force (IOTF), to classify weight status and it is the way in which policy and government assess weight status in children in the UK as it is the most widely used tool to determine weight status.

Besides the methodological limitations, the main limitation due to the design of this study was not having PA at the year one assessment. If baseline PA data were available then analysis would have been able to identify how much FMS influences current and future PA and the cause and effect relationship could have been concluded. Furthermore, delta values for

PA could have been calculated and analysed to highlight the magnitude of change in relation to the change in FMS levels.

The interpretations of these results are limited due to potential confounding factors. As explained age was highlighted as a confounding factor, so was controlled for. This could have potentially been the case for other factors such as maturation. However, maturation was not measured at the time of data collection. Therefore the percentage of variances reports could be shared between FMS and other confounding variables such as maturation.

Due to the large sample size and the school used in this study was broadly representative of the Coventry area, results can be generalised a certain amount to the children of this age. Only one school was used in one city, so interpretation should be undertaken with caution and generalizability is still very limited. Therefore, larger scales studies are recommended to obtain results that can be generalised to a wider population and provide information that could be used by UK PE policy.

Only eight FMS were measured subjectively and two objectively. There is a multitude of other FMS that could have potentially been able to contribute to the predictive models. If other FMS were found to be better predictors to PA then this would be important information, not only to PE teachers and policy, but also to influence future interventions that aim to increase PA.

## 5.6 Conclusion

The current study has identified that a combination of previous and current FMS in girls and boys are better predictors of current PA levels. Therefore, FMS needs to be learned and practised for future success in participation and maintenance of PA. The results from this study suggest that FMS should be tested in primary schools so weaknesses can be identified in children and subsequently improved via intervention. Bryant et al., (2013) highlighted that children aged 8-10 years old have a lower mastery level in specific skills compared to children younger and older than them; therefore this would be a good target age for intervention. These results should be used to influence PE and health policy in the UK to help decrease obesity levels by increasing PA levels, by ensuring that all children are taught FMS from a young age to gain mastery and be physically active.[2]

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[2] The data from this chapter are published as follows: **Bryant, E.**, James, R., Birch, S., and Duncan, M. (2014) Does prior or current FMS predict future habitual physical activity (PA) levels and weight status? *Journal of Sports Science* 32(19):1775-82.

## 6.0 Can FMS mastery be increased through a six week physical activity intervention and does that intervention have positive effects on PA and weight status?

### 6.1 Introduction

It is well established that obesity levels in children have been increasing rapidly over recent years (British Heart Foundation, 2012). This is thought to be a consequence of the decreasing number of children meeting the recommended guidelines of 60 active minutes a day for PA (Fogelholm and Kukkonen-Harjula 2000; Donnelly et al., 2009). Children who are physically inactive demonstrate risk factors towards obesity, type two diabetes and various cardiovascular diseases such as, hypertension, high cholesterol and coronary heart disease, of which all of these conditions can be tracked from childhood through to adulthood (Wilkinson et al., 2011). The relationship between FMS and PA has been assessed in research to identify a possible cause for the decreasing PA levels (Mckenzie et al., 2002; Okely and Booth 2004; Barnett et al., 2008; Bryant et al., 2014). Research has demonstrated a positive correlation between FMS mastery level and PA (Vandorpe et al., 2012) and furthermore a negative relationship between FMS mastery and weight status (Erwin and Castelli, 2008).

Bryant et al., (2014) has suggested that a combination of previous current mastery in FMS can predict future PA levels in children. Bryant et al., (2014) identified that FMS could predict 34.9% and 16.3% of variation in PA levels in girls and boys, respectively. Okely et al., (2001) and Barnett et al.,

(2008) also reported variations, although smaller, in PA from previous FMS mastery. These findings demonstrate the importance of FMS competency in childhood for maintenance of PA levels and in turn a healthy weight status.

A key further step would be to determine whether it is possible to intervene and increase a child's FMS competency to acquire the benefit of sustained PA participation. The most effective type of intervention needs to be elucidated, taking into consideration the FITT (Frequency, Intensity, Time and Type) principles. With regards to these principles, research has reported that there is no difference in competency levels after interventions that range in weeks, months or years (Logan et al., 2011). This suggests that intensity and type are more important principles to focus on during the intervention. Vandaele et al., (2011) have reported that PA at a higher intensity is needed to develop skill competency. Also, Van Beurdon et al., (2003) reported that time spent on instructions is vital but may hinder the overall intensity of the session, however, Stratton et al., (2008) reports that the instruction of the FMS could be more important in the future.

There are three main options for where an intervention can be organised. The first option is for it to run in a community setting (eg, sports club, community centre). Children who are likely to go to a sports club, or a PA session, are more likely to be already physically active and already hold a higher FMS mastery level. For children to participate they will need commitment from parents/guardians to spend their time and potentially money to take them to the intervention sessions. For parents to take their children to a session it would need them to understand the importance of it, have time to take them and if they have multiple children then they may have

to take different aged children to different sessions. These barriers highlight that this would not be an ideal scenario to run an intervention to target high numbers of children and those children who need the most help.

The second option is to run an afterschool club. This option is more feasible than the first to obtain more children as they will already be at school and will not require parents to take them anywhere. This would require parents to pick children up at a different time and if children have siblings who are not attending an afterschool club then some parents may be reluctant to make multiple journeys. If children have other pre-existing commitments (eg, maths tutoring, music lesson) afterschool then will not be able to attend and obtain the benefits. Currently children who attend organised activity afterschool are more competent at performing the FMS and tend to have a healthy weight status (Vandorpe et al., 2011).

The third option is to run the intervention in the children's PE lesson at school. This eliminates the issues of reaching all children, the type of children that will attend and parents having to take their children. Children currently have two hours of statutory PE a week. To replace a PE lesson it still needs to be suitable to meet the purpose of PE. For this to be possible the aims of PE need to be established and this has controversy within literature over the past three decades (Green, 2008). In 1990, Alderson and Crutchley (1990) highlighted that there was no professional consensus of how someone becomes physically educated. This was not only in the UK but across Europe that had uncertainty of the nature and purpose of PE (Green, 2008).

In 2007, the National Curriculum for PE (NCPE; QCA, 2007) was designed, that stated that the aim of PE is to enable children to be independent and equipped for lifelong PA participation. Thus, PE needs to provide children with the skills and tools to be able to lead a physical active lifestyle (Green, 2008; Almend, 2012). An additional target for PE lessons proposed by the Association for Physical Education (2008) is that for 50% of the PE lesson children are moderate-vigorously active to contribute to the daily target for MVPA; 60 minutes of MVPA throughout the day (NICE, 2009). For some children their PE lesson is their only opportunity to meet their MVPA target, therefore teachers tend to focus on this when delivering their PE lessons (Hodges-Kulinna et al., 2003; Trudeau and Shephard, 2005). A review conducted by Fairclough and Stratton (2005) evaluated 40 studies that assessed MVPA in PE lessons and reported that overall students spent 40% of time in MVPA. The MVPA reported was gained by a variety of methodological approaches (team games, sports, exercise activities), although each of the 40 studies had pedagogical (class size, available space, organisation, teaching approaches and lesson content), inter-individual (age, BMI, BF%, FMS level, gender), and environmental (available space indoors and outdoors, equipment) variations. However, the best way for children to obtain a MVPA status in a PE lesson is during team games (Fairclough, 2003; Warburton and Woods, 1996) and children's PE lessons are being dominated by team games and sport (McName, 2005) to contribute to the MVPA target. By throwing children straight in to team games and sport in a PE lesson it does not provide them with the tools to lead an active lifestyle. PE lessons that are less active but promote the

teaching of skill-related fitness (Stratton et al., 2008) may be more important in the long term to provide children with the skills to be physically active in later life (Bryant et al., 2014); which is the main goal in the NCPE (QCA, 2007).

It would seem sensible to trial replacing one of the statutory PE lessons with an intervention focused on teaching the children the FMS needed to partake in PA; and identify if this has any significant positive effects on the children leading an active lifestyle and health indices such as weight status compared to children who have two statutory PE lessons focused on games.

Logan et al., (2011) conducted a meta-analysis of the effectiveness of interventions to enhance FMS competency. It was identified that children improved in FMS competency from pre to post intervention. Out of the 11 studies that met the inclusion criteria only two of the studies used a sample of typically developing children. The majority of the other samples used children with, or at risk of, developmental delay, therefore allowing room for greater improvement to be made. Five out of the 11 studies did not use a control group, thus not being able to identify if the improvement of FMS was due to the intervention or due to natural development. From the meta-analysis Logan et al., (2011) concluded that more interventions need to be conducted that aim to enhance FMS competency using typically developing children and assessment of a control group to identify the true effect of the intervention. Therefore, this study will use typically developing school children with the inclusion of a control group.

According to Stodden et al., (2008) PA participation level and weight status are direct results of a combination of actual and PMC. Stodden et al., (2008) explains that when children reach middle to-late childhood (7-10 years old) their cognitive ability has developed to a stage where they can compare themselves to their peers (Harter, 1999). Therefore, a relationship between AMC and PMC is highlighted because children are now cognitively developed enough to accurately perceive their AMC. Furthermore, children who obtain a higher PMC due to a higher AMC will perceive tasks as being easier and are more likely to engage in them. This engagement in PA will allow a child to practice and develop their AMC, sustain their PA level and maintain a healthy weight status (Stodden et al., 2008). Although previous research has identified significant relationships between PMC, PA levels and weight status (Southall et al., 2004; Stein et al., 2006; Hands et al., 2010; Jones et al., 2010) it needs to be distinguished if PMC can be changed alongside AMC through an intervention.

Based on the findings of the previous study (study 2) which found that FMS could predict PA levels, the present study will explore to identify if it is possible to teach and develop children's FMS levels through an intervention.

The aim of this study is firstly to run an exploratory six week trial of replacing one out of two statutory PE lessons a week focused on the teaching of FMS and secondly to observe changes in PA and physical self-perception.

### 6.1.1 Hypothesis

Experimental hypothesis: By replacing one PE lesson a week children will show positive changes in FMS mastery, habitual PA and self-perception immediately after the six week intervention, however, there will be no change to these variables in children who maintain their two statutory PE lessons.

## 6.2 Method

### 6.2.1 Sample

Two primary schools in the Coventry area were selected to take part in the study. To maintain consistency the schools were chosen from the same bracket of electoral wards (50-59%) for deprivation and socio-economic status (Coventry City Council, Key Statistics, 2012) as with the previous two studies in this thesis. When the schools were chosen, it was ensured that they were not currently and had not previously been part of any specialist PE programme/interventions. From the two schools 166 children took part in the study, consisting of Year 4 and 5 children with a mean (±SD) age of 8.3±0.4years (77 boys and 89 girls). Of the full sample 83 also acted as the control group (42 boys and 41 girls).

### 6.2.2 Anthropometric measurements

Children's body mass and height were measured to calculate BMI to be used to classify weight status. For a full description on how BMI was assessed refer to section 3.4. BMI was calculated as Kg/m$^2$, with the 1990 reference curves controlling for age and sex used to identify overweight and obese children (Cole et al., 1990). Children were classed as overweight if they were in the 85$^{th}$ centile and obese if in the 95$^{th}$ centile (Cole et al., 1990). Using these criteria, 64% of children were classified as 'normal weight' and 36% as 'overweight/obese'. Furthermore, calculation of BMI z scores were including using the 1990 reference curves (Cole et al., 1990).

Body fat percentage was calculated using skin fold body calliper readings. Readings were taken from two sites; tricep and the medial calf. The Slaughter et al., (1988) skin fold equation (BF% = (0.735*(Tricep+Medial Calf))+1) was used to calculate each child's body fat percentage. Further information on this protocol can be found in chapter 3.4.

### 6.2.3 Fundamental Movement Skill Assessment

### 6.2.3.1 Subjective measurement

Children performed eight FMS (run, hop, gallop, kick, catch, throw, balance and the jump). For a full description on how the FMS were assessed refer to section 3.3.1. Prior to analysis inter- and intra- rater reliability analysis was performed for all the FMS between each researcher and the

lead researcher. Inter-rater reliability was 91% and intra-rater reliability was 92% demonstrating good reliability (Jones et al., 2010).

### 6.2.3.2 Objective measurement

The sprint run and the jump were both measured objectively as time (sec) and height (m) respectively.

The sprint run and jump were both measured objectively for time (sec) and height (m) respectively. For a full description on how the objective measurement of FMS were assessed refer to section 3.3.2.

### 6.2.4 Physical activity assessment

PA was assessed using a sealed Yamax Digi-Walker (SW 700) worn over four days (two weekdays and two weekend days). For a full description on how PA data were recorded refer to section 3.6

### 6.2.5 Children's self-perception of skill ability assessment

To measure the children's physical self-perception of their own skill competence a modified version of The Perceived Physical Competence Subscale for Children questionnaire (PPCSC) was used (Harter, 1982). Harter's PPCSC (1982) has been used within literature as the structure it employs minimises social desirability in responses which most other scales assessing this construct suffer from. Originally, the PPCSC consisted of 26 self-efficacy questions focussed around large group and recreational activities. The questionnaire has been reduced to 10 questions that are

activities that children are likely to perform and have been shown to have good discrimination between self-efficacy levels. Felts and Brown (1984) tested the reliability of the PPCSC by assessing the Cronbach's α values which highlighted high consistency between items. The modifications made to the PPCSC in the present study replicate those used in previous studies (Horn and Hasbrook, 1987; Duncan and Duncan, 1991; Kimiecik, et al., 1996).

The questionnaire was completed in a classroom with the project coordinator and a class teacher. The structure of the questionnaire was explained to the children and they were asked to concentrate on their own answers and to be as honest as they could. Names were not used and the child's number was put at the top of the questionnaire. Children were reassured that no one would see their answers. Children were free to ask questions of the class teacher and the project coordinator (Bois et al., 2005).

### 6.2.6 Intervention

The intervention consisted of a six week programme that took place in the children's PE lessons. The intervention lasted six weeks due to the restrictions of the school terms being six weeks long. However, this makes the intervention realistic to be implemented and transferred straight into a school term. Baseline data was collected prior to the intervention starting. A six week programme was delivered by the project coordinator in the PE lesson and then post data and six week follow up data were recorded. The two schools involved in the intervention are both two form entry. This allowed

for a cross over design. This design was important to allow for a control group, but also for all the children in the year group to experience and to gain the potential benefits from the intervention which was important for the schools when access to children was discussed. Therefore, one class completed the six week intervention whilst the other class had their normal PE lessons thereby acting as the control group. Once the six week programme had been completed the two classes would swap over. Figure 6.1 describes the organisation of the intervention.

Collect baseline data (pre-test) in the last two weeks of term in PE lessons

EASTER

Class A                                                                    Class B

Intervention                    6 weeks                    Normal P.E

←——————————— Post test ———————————→

MAY HALF TERM

Class A                                                                    Class B

Normal P.E                    6 weeks                    Intervention

←——— 6 week follow up          Post test ———→

SUMMER

6 week follow up

SEPTEMBER
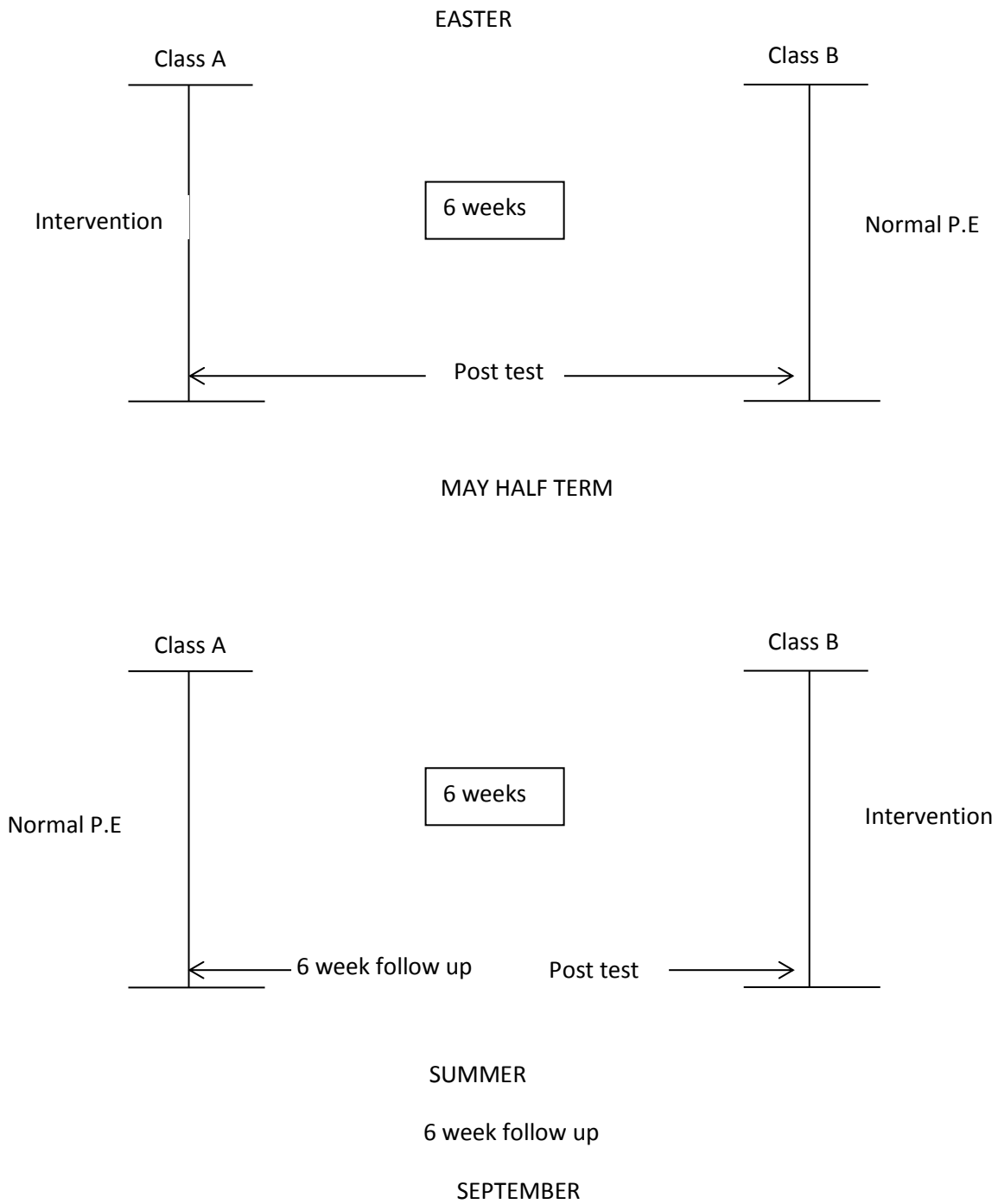
Figure 6.1 A flow diagram to describe the layout of the intervention

### 6.2.6.1 Baseline data

The base line data included: FMS mastery level, objective measurements of the sprint run and jump, all anthropometric data (to calculate BMI z scores and BF%), habitual PA and children's perceptions of their physical skill competency (described in section 3). This baseline data were collected two weeks prior to the six week programme.

### 6.2.6.2 Post and follow up data

The post and follow up data included exactly the same measurements as the baseline data, using the same methods. The post data was completed the same week or the week after the last session of the six week intervention. Follow up data was collected six weeks post the last session of the intervention.

### 6.2.6.3 Control content

Before the intervention started all children were partaking in two statutory PE lessons a week taken by their class teacher. These focussed on teaching and playing team games. Once the intervention started the control group continued with this for six weeks whilst the intervention group had one of these sessions replaced by the intervention.

### 6.2.6.4 Intervention content

The intervention ran for one hour a week for the six weeks and replaced one out of two statutory PE lessons, whilst the control group remained with the two statutory PE lessons. The intervention was designed to increase the competency of all eight FMS (run, hop, gallop, kick, catch, throw, balance and jump) with the aim to increase PA participation and increase physical self-perception. The session that focused on improving FMS was a combination of circuit training to popular music and group activities to songs. The content of this intervention was not based solely on a previous intervention, but it took different positive aspects from other research to contribute to creation of this intervention. Firstly, research has identified that interventions need to engage children and should not become boring so that the children disengage (Logan et al., 2011), thus the use of circuits. By using circuits it allows the children to partake in each station and move on to a new station before they disengage. By changing activities after a few minutes it should help keep the children engaged and they will be more likely to learn (Sigelman and Rider, 2012). Secondly, Martin (1988) reported that with the use of music children can use the rhythm to help sequence the components of the skills and perform them better, therefore the use of songs to perform the skills were included in the session. Derri and Patcha (2007) identified that different teaching styles such as guided discovery may help retention of FMS mastery. The different methods of circuits and dance were used to maximise the child's learning. Finally, Mitchell et al., (2011) identified that if children have input in to interventions then FMS mastery can be

significantly increased, the children were involved in choosing the songs that were included in the intervention. By using the songs that are the children's preference they will be less likely to find it boring and disengage, which previous research has highlighted.

Children completed the same session for three weeks and then a different session for the remaining three weeks (see table 6.1). This allowed for progression to be made by the children. Gallauhue and Ozmun (2006) identify that progressions are vital for motor skill development to be displayed. The first three weeks concentrated on the technique of the skill and during the second three weeks the skills were made harder or put in to a competitive situation to aid the development of the skill (Yu and Liu, 2009; Chen and Chen, 2014). All children were progressed on after three weeks, whether the technique had been gained or not. This was done to maintain motivation of all the children and save any embarrassment and potential disengagement from the intervention. The second half of the intervention progressed the skill; children were still encouraged to practice the correct technique and peer reviewed each other, which has also been highlighted as an effective technique of learning (Gauvain and Rogoff, 1989; Fawcett 2005).

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Table 6.1 The content of the six week intervention (30 second rest between each activity).

| Weeks 1-3 | Aim | Content | Equipment |
|---|---|---|---|
| **Warm up (5 mins)** | To steadily increase the children's heart rate. Prepare the body for similar movements that they are about to undertake. | Dancing to a song (cha cha slide, DJ Casper). This song is popular for the age group completing the research and includes instructions that the children have to follow, for example, hopping, jumping and sliding. | CD player |
| **Instruction time (8 min)** | To identify key coaching points of each skill to the children. | Coaching points from the POC (NSW, 2003) were explained and demonstrated to the children. | N/A |
| **Circuits (3mins)** **1.Running** | The use of the hurdles will encourage children to lift their knees higher to increase efficiency of the sprint (NSW, 2003). | Running over hurdles. Hurdles would start on the lowest level (10cm) and increase in height each week (17.5 and 25cm). Children were instructed to stay on the balls of their feet and drive their arms. | Five agility hurdles (Appendix VI) |
| **2. Balance (3mins)** | For children to control the board by engaging core muscles to improve balance. | Standing on balance boards. They were instructed to not let the board touch the floor. If they found this to easy then they were told to close their eyes. They were instructed to tense their stomach muscles. | Eight wobble boards |

| | | | |
|---|---|---|---|
| **3.Throwing and catching (3mins)** | For children to learn the correct technique to throw and catch a ball. | Children were in pairs standing five metres apart and practiced throwing and catching to each other with a tennis ball. They were given instructions for the throw; start standing side on and to step forward with the opposite leg, and the catch; meet the ball with your hands and bring it in to your body. | Eight tennis balls and 16 cones |
| **4.Kicking (3mins)** | For the children to learn the correct technique of the kick. | Children stood five metres from each other in pairs and kicked a ball back to each other. Children were instructed to take a step and swing back the leg, and keep their eye on the ball. | Eight small soft round playground footballs |
| **Songs** | | | |
| **1 Jumping (Kriss Kross, Jump).** | For children to learn the technique of the jump through a song that they will engage with. | Children were demonstrated the correct technique of a counter movement jump and were asked to complete this jump every time they heard the word jump in the song. | CD player |
| **2 Hopping (One direction, One way or another).** | For children to learn the technique off hopping through a song that they will engage with. | Children were split into four teams. The children were demonstrated the correct technique of the hop with coaching points such as 'stay on your toes'. Children then completed hopping relays in their teams. | CD player, cones |
| **3 Gallop (PSY, Gangnam style)** | For children to learn the technique off galloping through a song that they will engage with. | Children were demonstrated the correct technique of the gallop and given coaching points such as, 'make sure your hips and shoulders stay straight and do not twist'. Children would gallop in a circle around the room and when the chorus came on they would all come to the middle of the hall and | CD player |

| | | perform the 'gangnam style' dance to the music | |
| --- | --- | --- | --- |
| **Cool down-song (Harlum shake)** | To progressively cool the body down with lighter exercise to decrease the children's heart rate and to recap the movements learnt in the session. | Children had to pick a skill that they had performed in the session and mime it to the speed of the music. This was repeated three times with them choosing a different skill each time. | CD player |

| Weeks 3-6 | Aim | Content | Equipment |
|---|---|---|---|
| **Warm up**<br><br>**(7mins)** | To steadily increase the children's heart rate. Prepare the body for similar movements that they are about to undertake. | Pirate ship game. Children were shouted out commands to which they had to perform a response to. These were:<br>• Starboard: side gallop to the right hand side of the hall<br>• Port side: hop to the left hand side of the hall<br>• Climb the riggings: pretend to climb up a ladder getting their knees high and parallel to the ground.<br>• Scrub the deck: the children had to get in the floor on their hands and knees pretending to wash the floor.<br>• Invasion: children had to pretend to throw bombs at other pirates<br>• Spying: children had to pretend to throw bombs at invading pirates.<br>• Walk the plank: children had to stand on one leg as if they were on the end of a plank. | N/A |
| **Instruction time**<br><br>**(8 mins)** | To identify key coaching points of each skill to the children. | Coaching points from the POC (NSW 2003) were explained and demonstrated to the children. | N/A |
| **Circuits 1.Hopping (3mins)** | To be able to hop over all the hurdles without the use of the other leg. | Hurdles were set at the lowest level and children were asked to hop on one leg over each hurdle. Legs were then alternated between goes. | Five agility hurdles (Appendix VI) |
| **2.Kicking (3mins)** | To put the technique of the kick that the children have learnt in to practise | Yellow stars were stuck on the wall and children had to kick and aim at the star. If they hit a star they scored one point. | Six cardboard stars and four small soft |

| | | | |
|---|---|---|---|
| | via competition. | Children would compete against their partner | playground footballs (Appendix VI) |
| **3.Throwing (3mins)** | To put the technique of the throw that the children have learnt in to practice via competition. | Multi coloured cut outs of hands were stuck on to a wall and children had to throw a tennis ball aiming at the hands. If they hit a hand then they would score one point. Each child competed against their partner. | Six cardboard hands and four tennis balls (Appendix VI) |
| **4.Jumping (3mins)** | To complete the jump on a trampet to help increase height and encourage children to control the jump. | Children would do three consecutive jumps on a trampet, with the final jump landing on a mat in front. | Trampet (Appendix VI) |
| **5.Balance (3mins)** | To successfully walk along the benches without falling off. | Balance. Children would walk along three upside down gym benches with a cone on their head. | Three gymnasium benches. (Appendix VI) |
| **Relays (6 mins)** | To successfully complete the gallop and the run in a competitive situation. | Children remained in their five teams and completed running and galloping relay races. Children were demonstrated the correct technique and given coaching points. | 10 cones |
| **Cool down- game (7mins)** | To play a more static game to decrease heart rate and to successfully catch the ball in a competitive situation. | Children were split into two teams. Within each team children had to stand in two lines with a partner in front of them. Children had to throw the ball back and forth, from person to person, and work it up the line so that everyone had to touch the ball. If someone dropped that ball then that team had to start again from the beginning. The first team to get the ball to the other end without dropping it were the winners. To begin | Two tennis balls |

with, children had to have the hands behind their backs before catching that ball. This was to prove that it is much harder to catch a ball if you don't have your hands prepared to catch. It then would progress to having your hands waiting in a cupped position with a stable stance and as a consequence each team would complete the challenge quicker, therefore reinforcing the importance of being prepared.

## 6.2.7 Statistical Analysis

Firstly, the Q-Q plot and the kurtosis and skewness values for each variable were assessed to identify whether each variable was normally distributed. The values for skewness and kurtosis were all between <1 and >-1 and therefore normally distributed (Kline, 2005), allowing the use of parametric testing.

Discriminant function analysis was carried out on the complete data set to identify whether boys and girls were significantly different groups and should be analysed separately. For boys and girls the Wilks' Lambda value (0.499, p<0.001) was significant indicating that boys and girls were significantly different. As a result, statistical analysis was completed on girls and boys combined and separately.

For the analysis in this study, the FMS were analysed using the categorical data. If children displayed all components of each skill then they were given mastery, if they performed all but one of the components then they would be awarded near mastery, if they performed anything less the children were awarded no mastery. The distribution between these three categories is displayed as percentages.

Odds Ratios were calculated to describe how likely the children who completed the intervention were going to be at gaining mastery for all eight FMS compared to the control group. When completing this analysis, children who had full mastery at baseline and therefore could no longer improve were removed from the analysis. The number of children with full mastery at

baseline can be seen in table 6.1, 6.8 and 6.12, for all children, girls and boys respectively.

Paired samples t-tests were conducted to identify if there was a significant difference in sprint speed and jump height across the intervention and control period.

Raw data were analysed via a repeated measure ANOVA to identify if there were any significant differences between with pre, post and six week follow up intervention, pre and post control for changes in PA and self-perception scores. If a significance ($p<0.05$) was highlighted a Bonferroni post hoc analysis was completed to identify where these differences were. Also, delta values were calculated and analysed via a one way ANOVA with Bonferroni post hoc analysis to identify if the change in PA was significantly higher in the intervention or control group.

## 6.3 Results

### 6.3 Results for girls and boys combined

#### 6.3.1 Changes in subjective FMS

The number of children who are classed as having Mastery (M), Near Mastery (NM) and No mastery (NO) for all eight FMS pre and post intervention is displayed in Figure 6.2 . The same data for the control group is displayed in figure 6.3. Table 6.2 contains the exact percentage values that figure 6.3 and 6.3 are representing.
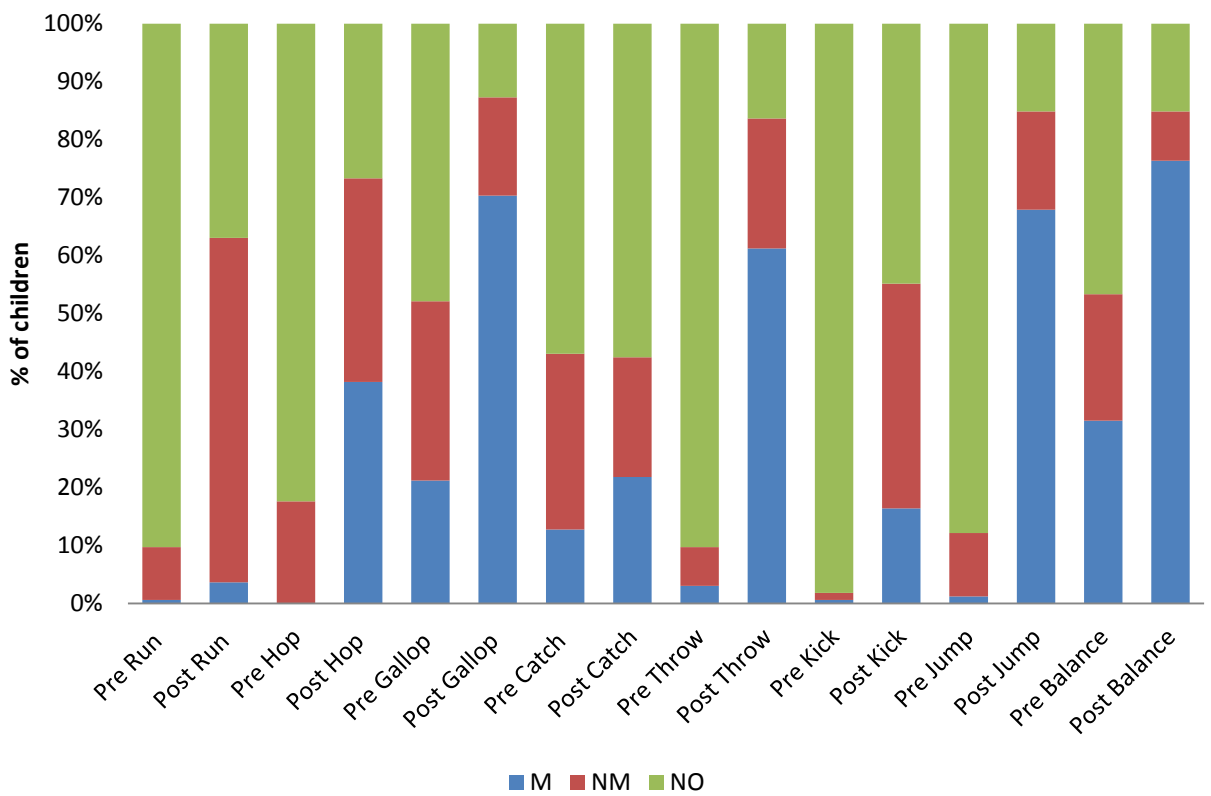
Figure 6.2. Percentage of children classed as M (Mastery), NM (Near Mastery) and NO (No mastery) for all eight FMS pre and post the six week intervention.
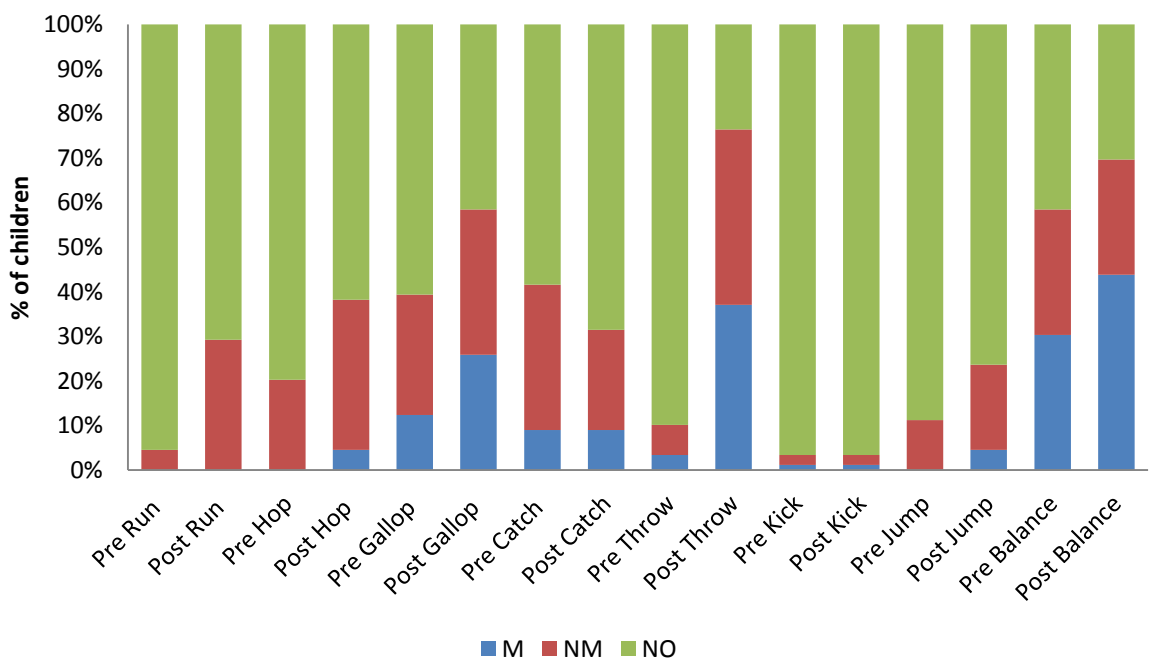


Figure 6.3. Percentage of children classed as M (Mastery), NM (Near Mastery) and NO (No mastery) for all eight FMS for pre and post a six week control.

Table 6.2 Percentage of children classed as having full mastery, near mastery and no mastery for all of the eight FMS pre and post for intervention (n=165) and control (n=89) groups and six week follow up for the intervention group.

| | Pre (%) | | | | | | Post (%) | | | | | | 6 Week Follow up (%) | | |
| | Intervention | | | Control | | | Intervention | | | Control | | | Intervention | | |
| Skill | M | NM | NO | M | NM | NO | M | NM | NO | M | NM | NO | M | NM | NO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run | 0.61 | 9.09 | 90.30 | 0.00 | 4.49 | 95.51 | 3.64 | 59.39 | 36.97 | 0.00 | 29.21 | 70.79 | 4.1 | 68.7 | 27.2 |
| Hop | 0.00 | 17.58 | 82.42 | 0.00 | 20.22 | 79.78 | 38.18 | 35.15 | 26.67 | 4.49 | 33.71 | 61.80 | 55.8 | 38.1 | 6.1 |
| Gallop | 21.21 | 30.91 | 47.88 | 12.36 | 26.97 | 60.67 | 70.30 | 16.97 | 12.73 | 25.84 | 32.58 | 41.57 | 77.6 | 21.1 | 1.4 |
| Catch | 12.73 | 30.30 | 56.97 | 8.99 | 32.58 | 58.43 | 21.82 | 20.61 | 57.58 | 8.99 | 22.47 | 68.54 | 35.4 | 58.5 | 6.1 |
| Throw | 3.03 | 6.67 | 90.30 | 3.37 | 6.74 | 89.89 | 61.21 | 22.42 | 16.36 | 37.08 | 39.33 | 23.60 | 61.21 | 27.9 | 10.89 |
| Kick | 0.61 | 1.21 | 98.18 | 1.12 | 2.25 | 96.63 | 16.36 | 38.79 | 44.85 | 1.12 | 2.25 | 96.63 | 16.36 | 35.4 | 48.24 |
| Jump | 1.21 | 10.91 | 87.88 | 0.00 | 11.24 | 88.76 | 67.88 | 16.97 | 15.15 | 4.49 | 19.10 | 76.40 | 87.1 | 8.2 | 4.8 |
| Balance | 31.52 | 21.82 | 46.67 | 30.34 | 28.09 | 41.57 | 76.36 | 8.48 | 15.15 | 43.82 | 25.84 | 30.34 | 91.2 | 7.5 | 1.4 |

M = Full mastery, NM = Near Mastery, NO = No mastery

For both the intervention and the control group the number of children classed as having mastery increased post intervention. For the control group, the number of children who are classed as having M increases for all skills accept the run, catch and kick which all remain the same. For the skills that increase in number of children who have mastery in the control group, this increase is not to the same magnitude compared to the intervention group. The number of children who are classed as having mastery in the six week follow up to the intervention increases for all skills Except for the throw and kick. To examine if children are more likely to become mastered in each skill as a result of the intervention Odds Ratios (OR) were calculated and are presented in table 6.3. Children are more than three times as likely to master the catch and the jump as a result of the intervention compare to the control group. This is closely followed by the kick and the run, where children are over twice as likely to gain mastery compared to the control group. The throw is the least likely skill to be mastered as a result of the intervention.

Table 6.3 Odds ratios (OR) to predict the likelihood of having mastery of each skill if children completed the six week intervention compared to the control group.

| Skill | OR | 95% CI | |
|---|---|---|---|
| | | Lower | Upper |
| Run | 2.01 | 1.45 | 2.79 |
| Hop | 1.66 | 1.29 | 2.15 |
| Gallop | 1.56 | 1.29 | 1.89 |
| Catch | 3.02 | 2.12 | 4.31 |
| Throw | 0.98 | 0.91 | 1.06 |
| Kick | 2.3 | 1.96 | 3.01 |
| Balance | 1.32 | 1.09 | 1.59 |
| Jump | 3.55 | 2.45 | 5.14 |

### 6.3.2. Changes in objective FMS

The mean (±SD) for the jump height and sprint speed for the intervention and control group at each experimental stage are displayed in table 6.4.  The intervention and the control group significantly increase jump height post intervention (t(165) -2.918, p=0.004; t(82)-3.590, p=0.001, respectively).  For the sprint speed the intervention group did not significantly improve on their time post intervention (t(165) 1.93, p=0.055). However, the control group did get significantly slower post the six week control (t(82) -2.846, p=0.006).

Table 6.4 Mean ± SD for objectively measured FMS pre and post intervention and control.

|  | Intervention | | Control | | Intervention |
| --- | --- | --- | --- | --- | --- |
|  | Pre | Post | Pre | Post | 6 week follow up |
| Jump height (cm) | 21.45 ± 4.41 | 24.27 ± 11.71* | 19.28 ± 6.47 | 21.70 ± 3.94* | 25.30 ± 18.84 |
| Sprint speed (secs) | 2.34 ± 0.59 | 2.21 ± 0.80 | 2.20 ± 0.81 | 2.41 ± 0.54* | 2.18 ± 0.81 |

*significantly different from pre intervention or control (paired samples t test; p<0.05)

### 6.3.3 Changes in PA

Table 6.5 displays the mean (±SD) for the pedometer step counts at each experiment stage for both the intervention and control group. Bonferroni post hoc analysis identified  that PA levels, measured by pedometer step

counts, significantly increased both from baseline to post intervention and from baseline to the six week follow up (Table 6.5; $p<0.05$). Although all three measures of PA at the six week follow up were still significantly higher than baseline, they had decreased from the post intervention measure with the average daily steps significantly decreasing (Bonferroni post hoc; $p<0.05$). Children in the intervention and control groups were both significantly more active on weekdays compared to weekends (Bonferroni post hoc; $p<0.05$) at baseline. In the post measures both groups still had higher weekday steps compared to weekend steps, however, this was no longer significant (Bonferroni post hoc; $p>0.05$). The control group did not significantly increase in their PA levels in the post six week control measure. The intervention group increased significantly more than the control group post six weeks in all three PA measures (Bonferroni post hoc $p<0.05$)..Overall children in the intervention group significantly increased PA levels, whilst those in the control did not.

Table 6.5 Mean (±SD) for pedometer step counts for intervention group at baseline (n=166), post six weeks (n=150) and six week follow up (n=150) and for the control group at baseline (n=83) and post six week control (n=83).

| | Baseline | | Post six weeks | | Six week follow up |
|---|---|---|---|---|---|
| | Intervention | Control | Intervention | Control | Intervention |
| Average Daily Steps | 9582 ± 6109 | 10036 ± 8527 | 15190 ± 7782* | 10683 ± 8387 | 12076 ± 7896** |
| Average Weekend Steps | 8005 ± 3716 | 7433 ± 2885 | 14865 ± 9882* | 10078 ±1351 | 11090 ± 7920* |
| Average Weekday steps | 10616 ± 6400 | 10200 ± 4117 | 15491 ± 8372* | 12635 ± 1063 | 13123 ± 11330* |

*Results were significantly higher compared to baseline, Bonferroni post hoc; p< 0.001. ** Results were significantly lower compared to post intervention. Bonferroni post hoc; p< 0.001

## 6.3.4. Weight status

The mean (±SD) for the measures of weight status (BMI, BMI z score, BMI centile, BF%) are presented in table 6.6. The table also includes the percentage of children who were classed as overweight/obese (categorised using the centile cut offs provides by Cole et al.,1990), at each experimental stage of the intervention or control measures.

Table 6.6.  Mean and SD BMI, BMI z score, BF% and the percentage of overweight/obese children according to the 85th centile cut off for the intervention group at baseline (n=166), post six weeks (n=150) and six week follow up (n=150) and for the control group at baseline (n=83) and post six week control (n=83).

| Weight Status | Baseline | Post intervention | Baseline control | Post control | 6 week follow up |
|---|---|---|---|---|---|
| BMI (kg/m$^2$) | 18.0 ±2.9 | 18.0 ±3.0 | 18.3 ±3.3 | 18.3 ±3.1 | 18.0 ±3.8 |
| BMI z | 0.4 ±1.1 | 0.3 ±1.9 | 0.6 ±1.1 | 0.6 ±1.1 | 0.5 ±1.2 |
| BMI centile | 62.2 ±29.4 | 62.1 ±30.0 | 65.7 ±29.4 | 65.1 ±29.4 | 63.6 ±29.9 |
| % of OW/OB | 33 | 34 | 39 | 35 | 32 |
| BF% | 21.2 ±10.69 | 21.6 ±8.4 | 22.5 ±8.4 | 21.2 ±8.4 | 21.7± 9.5 |

### 6.3.5 Changes in physical self-perception

For the intervention group, physical self-perception scores significantly increased from baseline to post intervention (Bonferroni post hoc p=0.027), and from baseline to the six week follow up (Bonferroni post hoc p=0.003). However, for the control group there was no significant change in self-perception scores (Bonferroni post hoc p=0.593). Table 6.7 displays the mean and confidence intervals for the self-perception scores for the intervention and control group at each experimental stage.

Table 6.7. The mean and confidence intervals for self-perception according to the PPCSC for intervention group at baseline (n=166), post six weeks (n=150) and six week follow up (n=150) and for the control group at baseline (n=83) and post six week control (n=83).

|  | Mean | 95% Confidence interval | |
| --- | --- | --- | --- |
|  |  | Lower | Higher |
| **Intervention Group** |  |  |  |
| **Baseline** | 25.6 | 24.4 | 26.9 |
| **Post intervention** | 29.9 | 28.8 | 31.0 |
| **6 week follow up** | 28.5 | 27.2 | 29.7 |
| **Control Group** |  |  |  |
| **Baseline** | 26.9 | 24.1 | 29.7 |
| **Post control** | 26.1 | 23.7 | 28.4 |

## 6.4 Results for boys individually

### 6.4.1 Changes in subjective measures of FMS

The number of boys who are classed as having Mastery (M), Near Mastery (NM) and No mastery (NO) for all eight FMS pre and post intervention is displayed in Figure 6.4. The same data for the control group is displayed in figure 6.5. Table 6.8 contains the exact percentage values that figure 6.4 and 6.5 are representing.
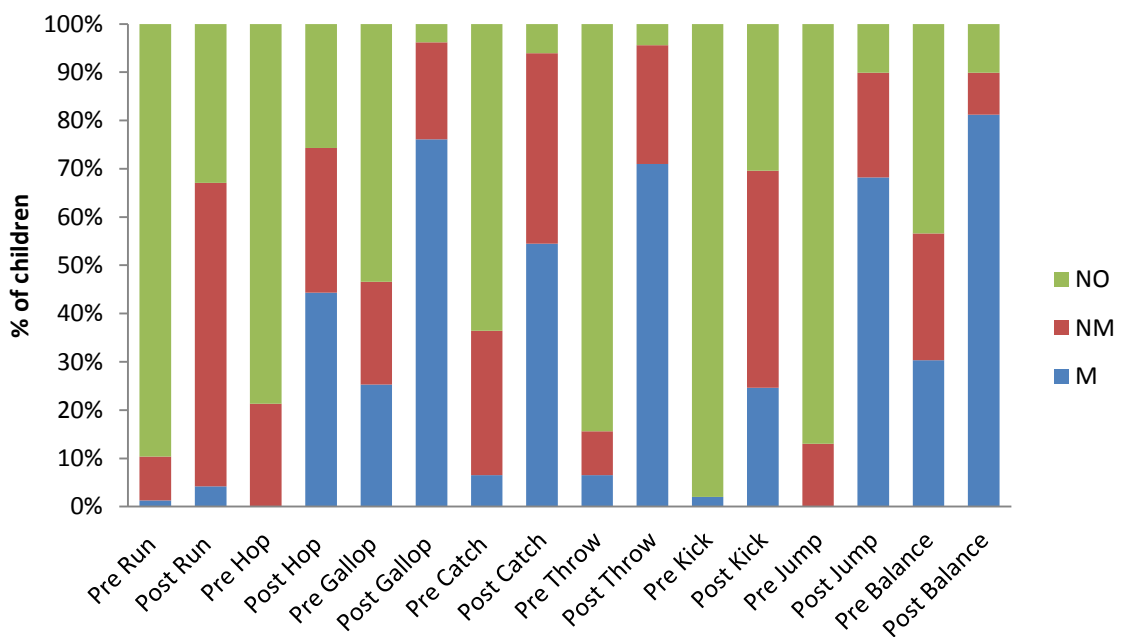


Figure 6.4. Percentage of boys classed as M (Mastery), NM (Near Mastery) and NO (No mastery) for all eight FMS pre and post the six week intervention.
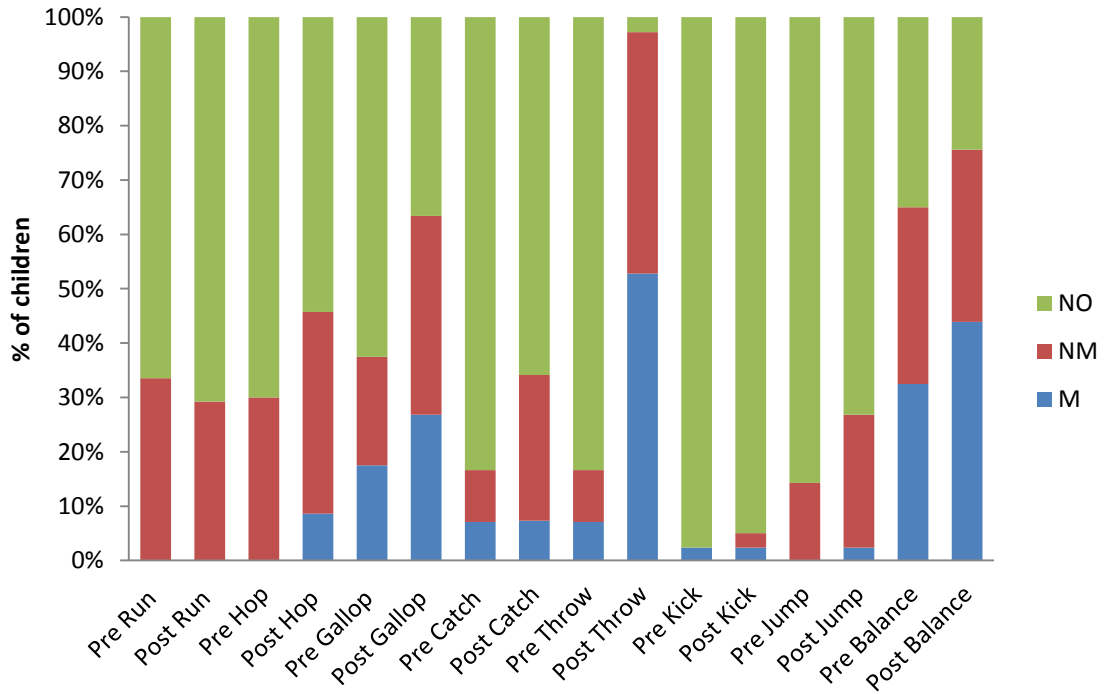
Figure 6.5. Percentage of boys classed as M (Mastery), NM (Near Mastery) and NO (No mastery) for all eight FMS for pre and post a six week control.

Table 6.8 Percentage of boys classed as having full mastery, near mastery and no mastery for all of the eight FMS pre and post for the boys in the intervention (n=165) and control (n=89) groups

| | Pre (%) | | | | | | Post (%) | | | | | | 6 week follow up (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Intervention | | | Control | | | Intervention | | | Control | | | Intervention | | |
| Skill | M | NM | NO | M | NM | NO | M | NM | NO | M | NM | NO | M | NM | NO |
| Run | 1.3 | 9.1 | 89.6 | 0 | 4.8 | 95.2 | 4.2 | 62.9 | 32.9 | 0 | 29.2 | 70.7 | 5.5 | 69.9 | 24.7 |
| Hop | 0 | 21.3 | 78.7 | 0 | 30 | 70 | 44.3 | 30 | 25.7 | 8.6 | 37.1 | 54.3 | 52.1 | 39.7 | 8.2 |
| Gallop | 25.3 | 21.3 | 53.4 | 17.5 | 20 | 62.5 | 76.1 | 20.1 | 3.8 | 26.8 | 36.6 | 36.6 | 80.8 | 19.2 | 0 |
| Catch | 6.5 | 29.9 | 63.6 | 7.1 | 9.5 | 83.3 | 54.5 | 39.4 | 6.1 | 7.3 | 26.8 | 65.9 | 35.6 | 56.2 | 8.2 |
| Throw | 6.5 | 9.1 | 84.4 | 7.1 | 9.5 | 83.3 | 71 | 24.6 | 4.4 | 52.8 | 44.4 | 2.8 | 60.3 | 23.3 | 16.4 |
| Kick | 2 | 0 | 98 | 2.4 | 0 | 97.6 | 24.6 | 45 | 30.4 | 2.4 | 2.6 | 95 | 15.1 | 38.4 | 46.6 |
| Jump | 0 | 13 | 87 | 0 | 14.3 | 85.7 | 68.2 | 21.7 | 10.1 | 2.4 | 24.4 | 73.2 | 86.3 | 11 | 2.7 |
| Balance | 30.3 | 26.3 | 43.4 | 32.5 | 32.5 | 35 | 81.2 | 8.7 | 10.1 | 43.9 | 31.7 | 24.4 | 84.9 | 12.3 | 2.7 |

M = Full mastery, NM = Near Mastery, NO = No mastery

For the intervention group the amount of boys who were classed as having mastery, increased for all eight skills. This was similar for the control group; except for the kick which remained the same for children being classed as having mastery. Similar to the combined gender data, the magnitude of increase in numbers of children being classed as having mastery was much bigger in the intervention group. Table 6.9 displays the OR to determine how likely the boys will be to gain mastery or near mastery as a result of the intervention compared to the control group. With consideration of the OR, boys are over three times more likely to master the jump if they complete this intervention. This is closely followed by the catch and run which is just under three times and just over twice as likely to gain mastery as a result of the intervention, respectively. The skill that boys are least likely to master as a result of the intervention compared to the control group is the throw.

Table 6.9 Odds ratios (OR) to predict the likelihood of having mastery of each skill if boys completed the six week intervention compared to the control group.

| Skill | OR | 95% CI | |
|---|---|---|---|
| | | Lower | Upper |
| Run | 2.29 | 1.39 | 3.80 |
| Hop | 1.62 | 1.10 | 2.39 |
| Gallop | 1.63 | 1.23 | 2.17 |
| Catch | 2.96 | 1.84 | 4.77 |
| Throw | 0.99 | 0.93 | 1.07 |
| Kick | 1.4 | 0.46 | 2.4 |
| Balance | 1.34 | 1.00 | 1.78 |
| Jump | 3.35 | 2.01 | 5.59 |

## 6.4.2 Changed in objective FMS

The mean (±SD) for the jump height and sprint speed for the intervention and control group at each experimental stage are displayed in

table 6.10. The boys in the intervention group do not significantly increase their jump height (t(76) -1.821, p=0.073) but they do significantly increase their sprint speed (t(76)2.018, p=0.047). For the control group the boys sprint time became slower, but this was not significant (t(41) -2.248, p=0.075), however the control group did significantly increase their jump height (t(41) -1.828, p=0.03).

Table 6.10 Mean ± SD for objectively measured FMS pre and post intervention and control.

|  | Intervention | | Control | | Intervention |
| --- | --- | --- | --- | --- | --- |
|  | Pre | Post | Pre | Post | 6 week follow up |
| Jump height (cm) | 21.6 ±4.9 | 25.3 ±16.5 | 19.4 ±6.4 | 21.3 ±4.2* | 23.8 ±4.5 |
| Sprint speed (secs) | 2.09 ±0.69 | 1.96 ±0.86* | 2.18 ±0.75 | 2.36 ±0.45 | 2.17 ±0.67 |

*significantly different from pre intervention or control (p<0.05)

### 6.4.3 Changes in PA

The mean (± SD) of pedometer step counts are presented in table 6.11 for all three measure of PA (average daily, weekday and weekend steps) for both the intervention and control group at each experimental stage. Figure 6.6 displays the mean (±SD) of pedometer step counts for boys for intervention group at baseline, post six weeks and for the control group at baseline (n=41) and post six week control. For the boys in the intervention group they significantly increased in all three measures of PA post intervention (Bonferroni post hoc; p< 0.001). In the six week follow up of the intervention group all three measures had decreased from the post intervention measures and this decrease was significant for average weekday steps (Bonferroni post hoc; p< 0.001). All three measures at the six

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week follow up were still significantly higher compared to the baseline

measure (Bonferroni post hoc; p< 0.001). The boys in the control group

increased in all three measures, however these were not significant. For

average daily steps the intervention group increase significantly more

compared to the control group (Bonferroni post hoc; p< 0.001) (figure 6.6).

Table 6.11 Mean (±SD) of pedometer step counts for boys for intervention group at baseline (n=77), post six weeks (n=69) and six week follow up (n=69) and for the control group at baseline (n=42) and post six week control (n=42).

| Boys | Intervention | | Control | | Intervention |
|------|--------------|------|---------|------|--------------|
| PA | Baseline | Post | Baseline | Post | Six week Follow up |
| ADS | 9769 ± 3178 | 15786 ± 8324* | 9441 ± 3425 | 12172 ± 10898 | 13240 ± 8038* |
| AWDS | 8329 ± 3233 | 15631 ± 11519* | 7846 ± 3102 | 11848 ± 1806 | 12660 ± 11184** |
| AWES | 11158 ± 4257 | 15917 ± 8748* | 10925 ± 4965 | 14739 ± 1352 | 14104 ± 8207* |

ADS – Average Daily Steps, AWDS – Average Weekday Steps, AWES – Average weekend steps  *significantly higher compared to baseline (Bonferroni post hoc; p< 0.001) **significantly lower compare to post intervention (Bonferroni post hoc; p< 0.001)
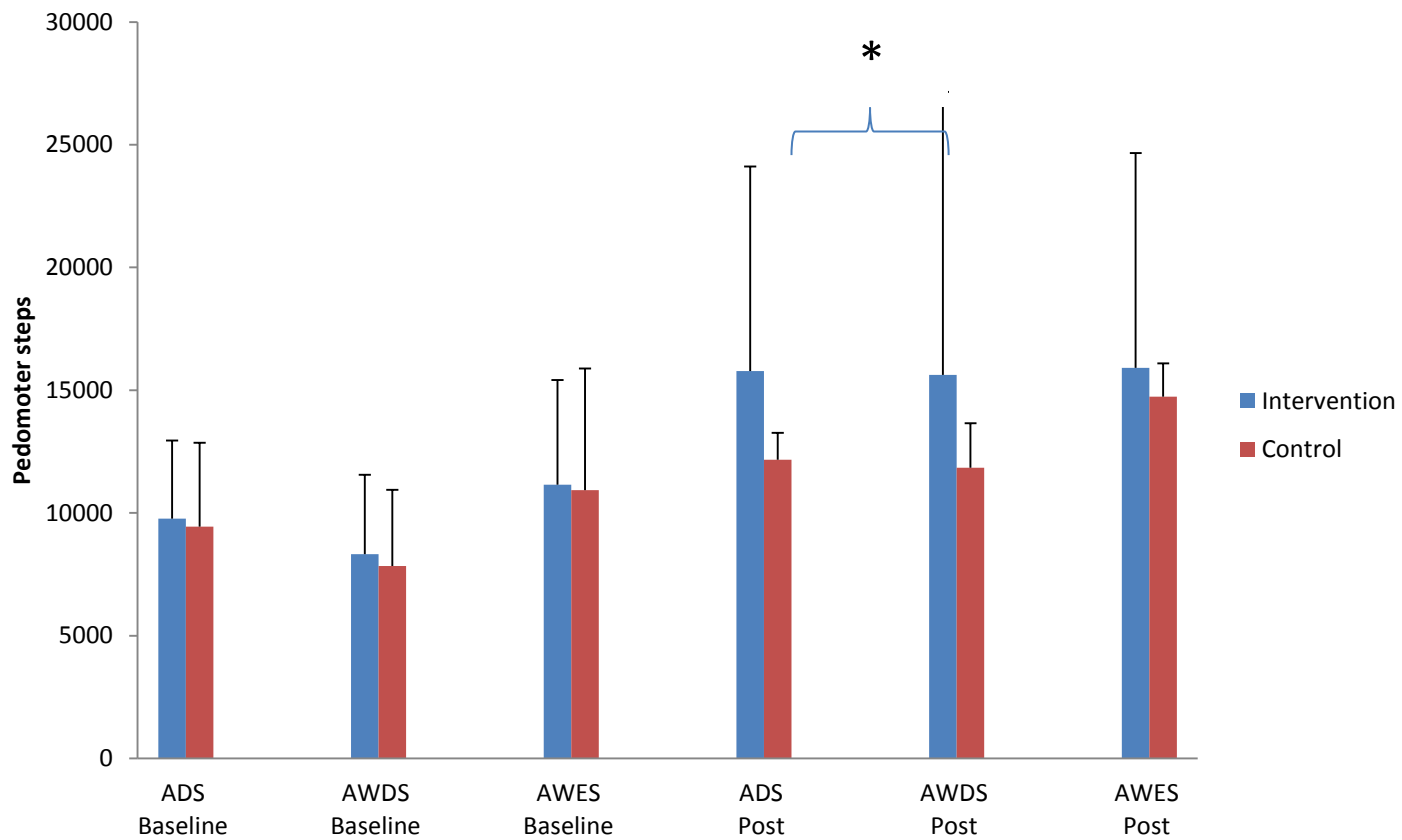
Figure 6.6 Mean (±SD) of pedometer step counts for boys for intervention group at baseline (n=77), post six weeks (n=69) and for the control group at baseline (n=42) and post six week control (n=42). * Intervention group significantly increased more than the control group (Bonferroni post hoc; p< 0.001).

## 6.5 Results for girls individually

### 6.5.1 Changes in subjective FMS

The number of girls who are classed as having Mastery (M), Near Mastery (NM) and No mastery (NO) for all eight FMS pre and post intervention is displayed in Figure 6.7. The same data for the control group is displayed in figure 6.8. Table 6.12 contains the exact percentage values that figure 6.7 and 6.8 are representing.
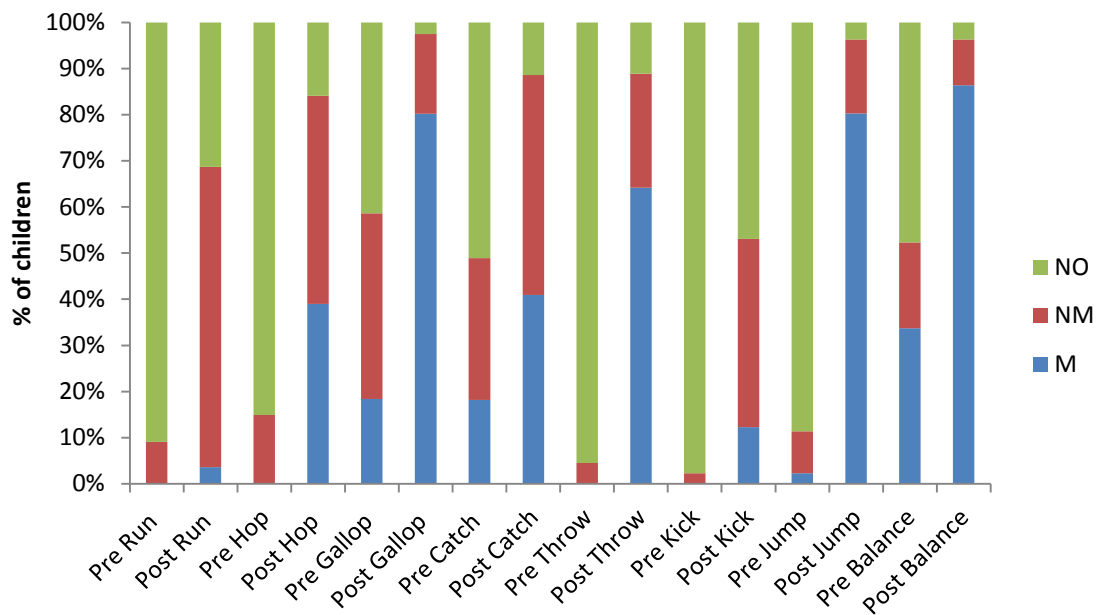


Figure 6.7. Percentage of girls classed as M (Mastery), NM (Near Mastery) and NO (No mastery) for all eight FMS pre and post the six week intervention.
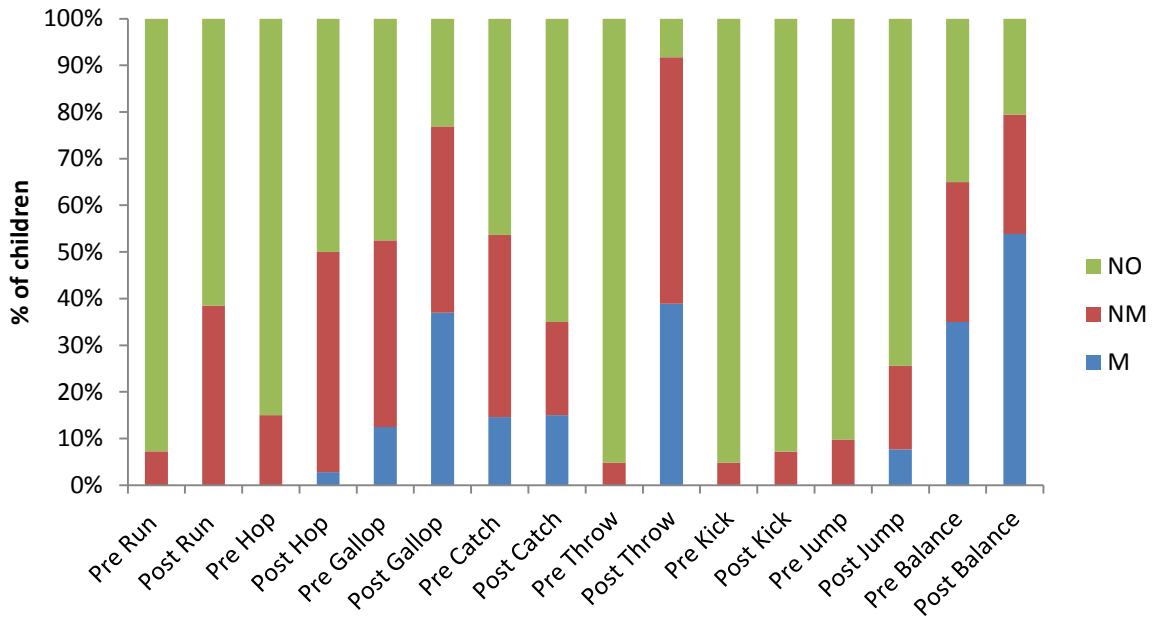
Figure 6.8. Percentage of girls classed as M (Mastery), NM (Near Mastery) and NO (No mastery) for all eight FMS for pre and post a six week control

Table 6.12 Percentage of children classed as having full mastery, near mastery and no mastery for all of the eight FMS pre and post for the girls in the intervention (n=165) and control (n=89) groups

| | Pre (%) | | | | | | Post (%) | | | | | | | | |
| | Intervention | | | Control | | | Intervention | | | Control | | | Intervention | | |
| Skill | M | NM | NO | M | NM | NO | M | NM | NO | M | NM | NO | M | NM | NO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run | 0 | 9.1 | 90.9 | 0 | 7.3 | 92.7 | 3.6 | 65.1 | 31.3 | 0 | 38.5 | 61.5 | 2.7 | 67.6 | 29.7 |
| Hop | 0 | 14.9 | 85.1 | 0 | 15 | 85 | 39 | 45.1 | 15.9 | 2.8 | 47.2 | 50 | 59.5 | 36.5 | 4.1 |
| Gallop | 18.4 | 40.2 | 41.4 | 12.5 | 40 | 47.5 | 80.2 | 17.3 | 2.5 | 33.3 | 35.9 | 30.8 | 74.3 | 23 | 2.7 |
| Catch | 18.2 | 30.7 | 51.1 | 14.6 | 39 | 46.3 | 40.9 | 47.7 | 11.4 | 15 | 20 | 65 | 35.1 | 60.8 | 4.1 |
| Throw | 0 | 4.5 | 95.5 | 0 | 4.9 | 95.1 | 64.2 | 24.7 | 11.1 | 38.9 | 52.8 | 8.3 | 59.5 | 32.4 | 8.1 |
| Kick | 0 | 2.3 | 97.7 | 0 | 4.9 | 95.1 | 12.3 | 40.7 | 46.9 | 0 | 7.2 | 92.8 | 9.5 | 32.4 | 58.1 |
| Jump | 2.3 | 9.1 | 88.6 | 0 | 9.8 | 90.2 | 80.2 | 16 | 3.7 | 7.7 | 17.9 | 74.4 | 89.2 | 4.1 | 6.8 |
| Balance | 33.7 | 18.6 | 47.7 | 35 | 30 | 35 | 86.4 | 9.9 | 3.7 | 53.8 | 25.6 | 20.5 | 95.9 | 4.1 | 0 |

M = Full mastery, NM = Near Mastery, NO = No mastery

For the intervention group the amount of children who were classed as having mastery, increased for all eight skills. This was similar for the control group; except for the kick and the run which remained the same for children being classed as having mastery. Similar to the combined gender data, the magnitude of increase in numbers of children being classed as having mastery was much bigger in the intervention group. Table 6.14 displays the OR to determine how likely the girls will be to gain mastery or near mastery as a result of the intervention compared to the control group. With consideration of the OR, the girls are over three times more likely to master the jump and catch if they complete this intervention. The skills that the girls are least likely to master as a result of the intervention compared to the control group are the throw and kick.

Table 6.13 Odds ratios (OR) to predict the likelihood of having mastery of each skill if girls completed the six week intervention compared to the control group.

| Skill | OR | 95% CI | |
|---|---|---|---|
| | | Lower | Upper |
| Run | 1.79 | 1.17 | 2.23 |
| Hop | 1.68 | 1.28 | 2.36 |
| Gallop | 1.5 | 1.17 | 1.93 |
| Catch | 3.1 | 1.82 | 5.27 |
| Throw | 0.97 | 0.86 | 1.10 |
| Kick | 0.47 | 0.37 | 0.60 |
| Balance | 1.29 | 1.02 | 1.65 |
| Jump | 3.75 | 2.20 | 6.41 |

### 6.5.2 Changes in objective FMS

The mean (±SD) for the jump height and sprint speed for the intervention and control group at each experimental stage are displayed in table 6.14. For the intervention group the girls significantly increased in their jump height (t(88)-5.636, p<0.001). Although the girls in the intervention group improved their sprint time this was not significant (t(88) 0.812, p=0.419). For the girls in the control group, they could jump significantly higher (t(40) -2.795, p=0.008) but sprint significantly slower(t(40) -2.167, p=0.036).

Table 6.14 Mean ± SD for objectively measured FMS pre and post intervention and control.

| | Intervention | | Control | | Intervention |
|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | 6 week follow up |
| Jump height (cm) | 21.2 ± 4.0 | 23.2 ± 4.5* | 19.4 ± 6.4 | 21.3 ± 4.2* | 26.8 ± 6.1* |
| Sprint speed (secs) | 2.41 ± 0.68 | 2.34 ± 0.85 | 2.18 ± 0.75 | 2.36 ± 0.45 | 2.13 ± 1.03 |

*significantly different from pre intervention or control (paired sample t test; p<0.05)

### 6.5.3 Changes in PA

The mean (± SD) of pedometer step counts are presented in table 6.15 for all three measure of PA (average daily, weekday and weekend steps) for both the intervention and control group at each experimental stage. Figure 6.8 displays the mean (±SD) of pedometer step counts for girls for intervention group at baseline, post six weeks and for the control group at

baseline (n=41) and post six week control. For the girls in the intervention group they significantly increased in all three measures of PA post intervention (Bonferroni post hoc; p< 0.001). In the six week follow up of the intervention group all three measures had decreased from the post intervention measures and this decrease was significant for average daily steps (Bonferroni post hoc; p< 0.001). All three measures at the six week follow up were still significantly higher compared to the baseline measure (Bonferroni post hoc; p< 0.001). The girls in the control group increased in all three measures, although these were not significant. For all three measures of PA the intervention group increase significantly more compared to the control group (Bonferroni post hoc; p< 0.001) (figure 6.9). Suggesting, children who complete this intervention will increase the amount of steps per day, whereas children who do not complete this intervention will not.

Table 6.15 Mean (±SD) of pedometer step counts for girls for intervention group at baseline (n=88), post six weeks (n=81) and six week follow up (n=81) and for the control group at baseline (n=41) and post six week control (n=41).

| Girls | Intervention | | Control | | Intervention |
| --- | --- | --- | --- | --- | --- |
| PA | Baseline | Post | Baseline | Post | Six week Follow up |
| ADS | 9419 ± 7857 | 14757 ± 7403* | 10745 ± 1218 | 8821 ± 2515 | 11293 ± 7775** |
| AWDS | 10141 ± 7822 | 15181 ± 8146* | 6939 ± 2593 | 7954 ± 3061 | 12463 ± 1306* |
| AWES | 7721 ± 4100 | 14309 ± 8558* | 9293 ± 2561 | 10198 ± 3653 | 10014 ± 4317* |

ADS – Average Daily Steps, AWDS – Average Weekday Steps, AWES – Average weekend steps *significantly higher compared to baseline (Bonferroni post hoc; p< 0.001) **significantly lower compare to post intervention (Bonferroni post hoc; p< 0.001).
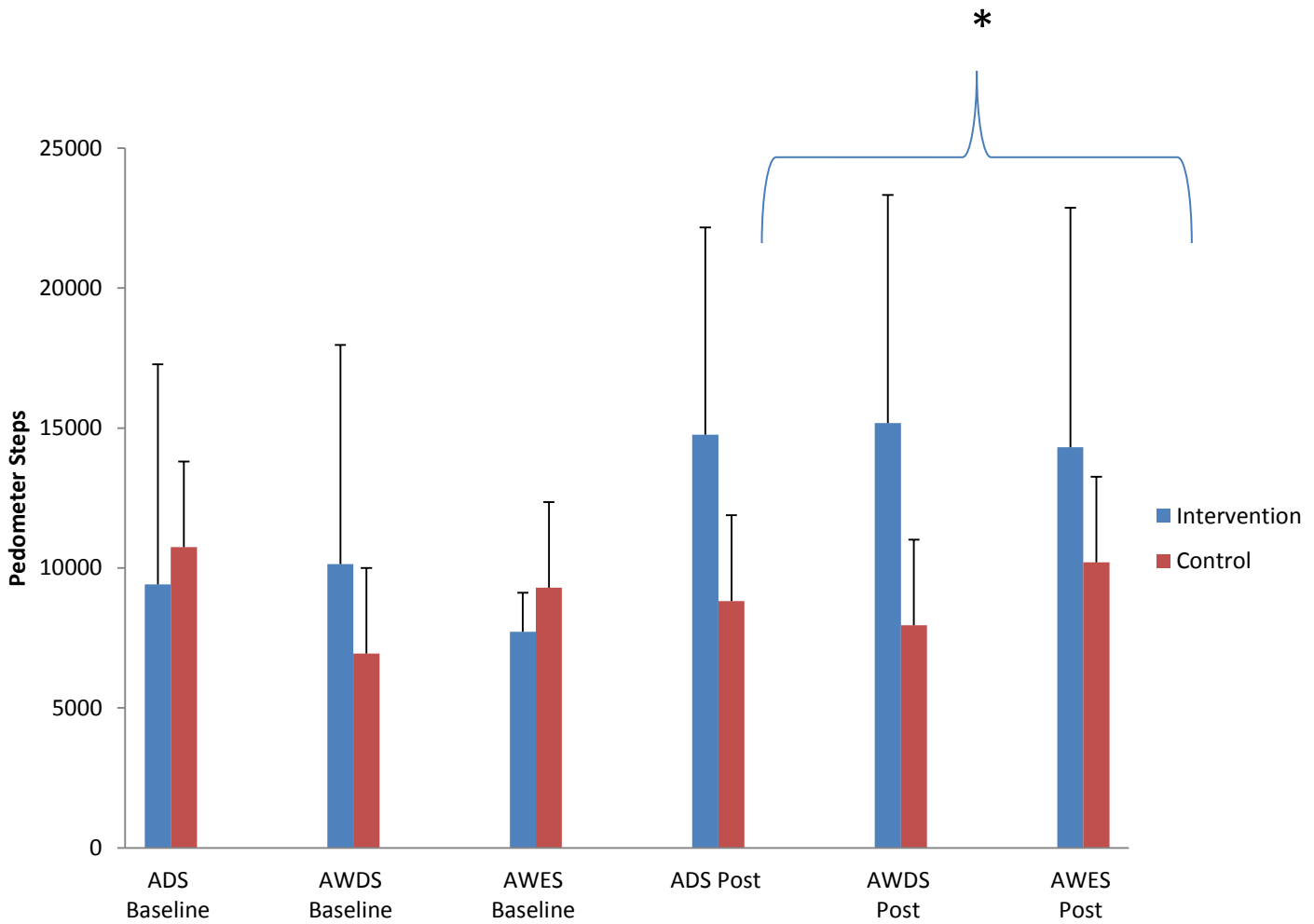
Figure 6.9 Mean (±SD) of pedometer step counts for girls for intervention group at baseline (n=88), post six weeks (n=81) and for the control group at baseline (n=41) and post six week control (n=41). Average Daily Steps (ADS), Average Weekday Steps (AWDS) and Average Weekend Steps (AWES). * Intervention group significantly increased more than the control group (Bonferroni post hoc; $p < 0.001$).

## 6.6 Discussion

Previous research has identified the importance of the mastery of FMS for maintenance of PA levels (Bryant et al., 2014) and a healthy weight status (Erwin and Castelli, 2008). There is a growing amount of evidence supporting the relationship between FMS competency and PA participation (Okley 2001; Van Beurden 2003; Graf 2004; Fisher 2005; Hamstra-wright 2006; Hume 2008; Williams 2008; Barnett 2009; Clif 2009; Dhondt 2009; Vandrope 2011; Mitchell 2011;). Therefore, the next stage and the purpose of this study was to understand if it was possible to teach, develop and increase FMS mastery in children by replacing one out of two statutory PE lessons for six weeks and to recognize the effects this might have on PA level. This current study has identified that the children who completed this intervention are more likely to gain mastery of FMS, significantly increase pedometer step counts and physical self-perception, thus accepting the first part of the hypothesis (that by replacing one PE lesson a week children will show positive changes in FMS mastery, PA and physical self-perception). However, the second part hypothesised (that the control group would not significantly change scores for FMS, PA and self-perception) was not accepted as this was the case for all these variables except FMS which also increased. Although, it is important to note that the amount of children in the intervention group who were classed as having mastery of the different skills increased to a higher magnitude compared to the control group. Furthermore, the use of odds ratios indicates that the children who

completed the intervention were more likely to gain mastery of the FMS when compared to the control group.

The study is novel as it presents a low cost FMS intervention which positively influenced FMS, PA and physical self-perception compared to a control group. Stodden et al., (2008) identified that a combination of AMC and PMC will influence PA and then weight status. To the author's knowledge, no other study has identified if all three of these variables will be influenced from an increase of AMC through an intervention. This study is also novel in that it sought to modify one school PE lesson per week rather than add additional PA sessions (such as work by Cliff et al., 2007; Graf et al., 2008) or to completely change the PE curriculum (Jones and Riethmuller, 2011). Thus, not only is the intervention effective it is ecologically valid (the materials and methods could realistically be repeated in a school by class teachers) and feasible for primary schools to implement.

## 6.6.1 Overall changes in FMS

The number of children who were classed as having mastery for all eight subjectively measured skills increased post intervention, with six of the skills continuing to gain more children as having mastery in the six week follow up (kick and throw remained the same). This is consistent with the findings of Mitchell et al., (2011) who reported a significant increase in the number of children who were classed as having mastery for all 12 FMS that were assessed after a minimum of a six week intervention. Mitchell et al's (2011) intervention was conducted on children aged 5-12 years old which

provided teachers with a FMS manual to use through PE lessons and fitness classes. At baseline, the children in Mitchell et al's study had a higher amount of children classed as having mastery levels (21.4-84.6%) compared to the children at baseline in this study (0-25.3%). Post intervention, the percentage of children now classed as having mastery of the skills in Mitchell et al's (2011) study ranged from 49.8-98.3%, compared to 3.6%-81.2 in the present study. Although Mitchells et al's (2011) study reports a larger amount of children as having mastery of the skills; the TGMD-2 was used to assess the FMS. Although it is still a process orient based method it only has 3-4 components for each skill and therefore it is much easier for children to gain mastery of the skills. This is similar for Hardy et al., (2010) who reported that 20.5-76% of children had mastery of the same FMS and they also used the TGMD-2 to assess FMS. In this current study the POC, which was used to assess FMS has 5-6 components for each skill, therefore making it much harder to gain full mastery of them. Okely and Booth (2004) also used the POC and also reported lower numbers of children classed as having mastery 0-35%. Although two different scales have been used between this intervention and Mitchell et al's (2011) intervention, the two skills with the lowest and highest percentage of children classed as having mastery, is also the lowest and highest skills post intervention. This finding suggests that if all skills are focused on throughout an intervention then they will develop at similar rates.

The current study's intervention lasted for six weeks, which according to the odds ratios that were calculated, was more successful at gaining FMS mastery compared to the control group who continued with their

normal PE lessons.  It would seem logical that the longer an intervention the more of an increase in skill level would be shown.  However, Graff et al., (2008), who conducted the four year intervention, did not report a significant increase and Van Beurden et al., (2003) who conducted the six month intervention did not report as big an increase in skill level compared to the current study's six week intervention.  Furthermore, Logan et al., (2011) conducted a review on the effectiveness of FMS interventions and reported a non-significant relationship between effect size of pre to post intervention and the duration of the intervention. Interventions that are too long, may become boring and children will disengage from the programme, therefore explaining why longer interventions do not report significant increases or don't achieve increases of a higher magnitude when compared to shorter interventions. Therefore, highlighting the importance of the content of an intervention compared to the duration.  Furthermore, interventions that have been reported tend to focus on purely the teaching of the skill or just providing time for children to play (Beurden et al., 2003 and Graff et al's 2008), unlike the current intervention that focused on using fun and relevant methods that the children would engage with, to maximise learning.

Logan et al., (2011) suggests that FMS mastery begins to plateau and that there is a critical amount of instruction time needed when teaching FMS. This would support the theory that FMS do not develop naturally but must be learnt and practiced (Haywood and Getchall, 2002). Although van Beurden et al., (2003) and Graff et al's (2008) studies were longer interventions than most, neither of the studies concentrated on teaching the FMS  but instead provided support or training for the teachers delivering the P.E lessons. By

concentrating on providing support it would suggest that primary school teachers need more formal training for teaching these skills and that there needs to be a focus on developing FMS in a PE lesson.

Although, the number of children who were classed as having mastery increased for all eight subjectively measured FMS post intervention, in the six week follow up, the two skills that did not gain any more children as being classed as having mastery were two object control skills; kick and throw. To be able to practice and maintain these skills children would need access to equipment (such as different sized playground balls), potentially limiting the time that children would be able to practice outside of the intervention and suggesting why they have not continued to improve in performance by the follow-up data collection. In contrast to this, all the other skills gained children who were classes as having mastery. The two skills that improved the most were the hop and jump. Children do not need any equipment to practice and develop these skills and are therefore more likely to practice them in their own time. Therefore, maximising the potential amount of time children may spend rehearsing these skills in their own time. A further explanation as to why certain skills may have been maintained better than others could be to do with the method in which they were taught throughout the intervention. In-between each circuit (where the children were aware of learning and practicing a skill; explicit learning) the children would dance to a popular song. Children were taught different moves to the music, but unknown to them they were actually the movement patterns for running, hopping, galloping and jumping. All of these skills carried on improving in the follow up assessments. This suggests that performing skills to relevant songs that

children will engage in will have long term positive effects on FMS performance. Martin (1988) reports that by performing the skill to music it can aid the learning of the skill. Martin (1988) explains that by using rhythm, which is naturally found in the human body, children can organise rhythmic stimuli and translate them into the execution of the skill. This can also be explained by Schmidt's (1975) schema theory. Schmidt (1975) explains that children do not need prior experience of performing that specific skill, but an experience of performing a similar movement pattern. This creates a recall schema that will be used to perform the skills. So by performing the movement pattern as a dance move the children would then use that recall schema to perform the skill in a physical activity or sport situation. This should be investigated further and to be taken into account for future interventions looking at increasing FMS competency.

As stated, the percentages of children that are classed as having mastery increased or remained the same in the six week follow up. Other studies have reported overall FMS competency at follow up (Cliff et al., 2007). Therefore, this does not allow conclusions to be made about the individual skills that carry on improving and those skills that don't. This highlights the importance of reporting the scores individually for FMS and not stating an overall motor score, as used in some previous research (Cliff et al., 2007; Lopes et al., 2011; Vandrope et al., 2011). By reporting the individual FMS scores it has identified that some skills are harder to master for more children and will need extra practice, or access to equipment, to master them. In the case of this study, it is the object control skills that need extra maintenance and this suggests that children need to be given time and

access to equipment, such as balls, to allow them to develop and maintain these skills.

Out of the two skills that were measured objectively the jump height significantly improved post intervention, however the sprint speed (acceleration) did not. Research has identified that locomotor skills such as the sprint run are harder to master (Westerndorp et al., 2011). This is reflected in the subjective result of the sprint run as it was the skill that the least amount of children could master. This suggests that the new/correct technique that the children have learnt is not yet autonomous and that the children still have to concentrate when performing the skill which inhibits their objective performance outcome of the sprint run. Further research is needed to identify how long it takes for each skill to become autonomous to influence the amount of time needed to be spent in PE lessons in primary school. When children learn a new skill for the first time, they will get to the autonomous stage of learning quicker compared to when having to re learn a new skill (Fitts and Posner, 1967). The objective measure of the sprint run was measured over 10m, therefore assessing acceleration rather than sprint speed. The technique that the children would have learnt is appropriate for sprinting at speed, not the acceleration phase of the sprint. This this would explain why the children improved in the subjective measure and not the objective measure.

The percentage of children classed as having mastery increased for six out of the eight skills in the control group (not for the run and kick). Initially when the control group improved alongside the intervention group it would suggest that the change was not down to the intervention. However, the

control groups were in a different class but in the same year group and from the same school. The children in the intervention group had friends in the control group and were teaching them the skills they had learnt in the playground; this was reported to the lead researcher by the children who participated in the intervention sessions. This finding is consistent with Foweather et al., (2008) who also found an increase in skill level in the control group when running an intervention to increase FMS competency. Similar to the current study, Foweather et al., (2008) used control groups from the same school, however, other intervention studies that have used a control group from a different school do not find significant improvements in the post measures for controls (Van Beurden et al., 2003). This highlights the importance of using separate schools as control groups to control for this limitation. Although, the control groups did significantly improve, the odds ratios that were calculated highlight that children who participated in the intervention were more likely to gain mastery of all the skills compared to the control group. This supports Logan et al's (2011) theory that children need a critical amount of instruction time to optimise the learning and mastery of the FMS. The children in the control group would have only gained instructions from their peers and would not have been able to watch a completely accurate demonstration of each of the skills. When humans observe a process 'mirror neurons' are activated and then reactivated when performing that skill (Gazzola et al., 2007). Therefore, the children in the intervention group would have been subject to more demonstrations, which would have activated more 'mirror neurons' and aided the development of the skills.

The findings from this study indicate that an intervention in one group of children has wider benefits by significantly increasing FMS mastery in another group of children. From the perspective of the children this is a positive consequence. As stated the number of children who are classed as having mastery of the FMS increases for both the intervention group and the control group. This is inconsistent with previous research that had control groups at different schools to the intervention groups (Van Beurden et al., 2003). Although the odds ratios that were calculated highlight that children in the intervention group are more likely to gain mastery of FMS compared to the control. If the control group from this study was at a different school and the children did not improve then the odds ratios potentially could have been much bigger. Therefore, these results do not reflect the true effect of the intervention.

The reasons discussed as to why the control group also increased numbers of children who had mastery of the skills is speculative and this improvement could be down to the development of the children or a learning effect of repeating the tests just six weeks apart.

## 6.6.2 Changes in FMS for boys and girls separately

Children at this age (8-10 years) are pre pubertal and should be somatically the same (Malina et al., 2004). Previous research has identified that there tends to be a gender bias in FMS performance, whereby girls are relatively better in balance and the jump and boys in the kick, catch and throw (Bryant et al., 2013; Jones et al., 2010; Hardy et al., 2011). This has

been concluded to be a result of socialisation into gender specific activities (Blakemore and Renee, 2005). From this gender bias in FMS performance some studies have suggested that future interventions should take into account this gender bias (Beurden et al., 2003). In this current study the percentage of boys and girls who reached mastery of the six skills is very similar (table 6.8 and 6.12). This suggests that by creating a broad intervention that children will engage in, it will be suitable for both genders at this age. In contrast to this, the number of boys classed as having mastery of the kick improved by 22.6% compared 12.3% of girls. These results are very similar to Van Beurden et al., (2003) who also found an increase in the number of boys classified as having mastery of the kick was 21.1% compared to 12.1% of girls. Furthermore, in this study the number of boys who were classed as having mastery of the catch improved by 48% compared to 22.7% of girls. This is the opposite for Van Beurden et al., (2003) who reported that the number of girls classed as having mastery of the catch increased by 22.72% compared to 11.38% of boys. In addition to this Van Beurden et al., (2003) reported that the number of boys classed as having mastery for the throw was double the amount of the girls (14% compared to 7%). Van Beurden et al's (2003) study was also a very broad intervention that concentrated on providing support for teachers, lesson plans to teach FMS and funding for equipment. From the inconsistent results between the two studies for the amount of boys and girls that gain mastery for the different skills there does not seem to be an overall pattern. However, more interventions would need to be conducted to conclude any kind of pattern. This does suggest that the magnitude of children that will gain

mastery in certain skills will be dependent on the content of the intervention sessions. Therefore, the methods used to teach the kick and the catch in this current study would seem to favour boys and girls respectively. Although, the girls improved more than the boys, the number of boys classed as having mastery of the catch was still higher than the girls post intervention.

In regards to the odds ratios, both girls and boys from the intervention are more likely to gain mastery in all eight skills compared to the control group. For six out of the eight skills, boys are more likely to gain mastery in the skills compared to girls (jump and catch for the girls). This suggests that actually the boys benefited more from the intervention compared to the girls. As stated the girls and boys all improve by similar amounts post intervention for the majority of skills (six out of eight). Suggesting, that girls are more likely to teach their friends in the playground, which resulted in more of the girls in the control group to gain mastery and explain why the odds ratios for boys were higher compared to girls. This is speculative and again this study would have benefited from having the control group from a different school.

### 6.6.3 Physical activity changes

Children who completed the intervention were associated with having higher PA levels compared to the children who did not complete the intervention. PA levels significantly increased in post intervention and in the six week follow up compared to baseline for the intervention group (Table 6.5). Van Beurden et al., (2003) also found a significant increase by 7.8% of time spent in MVPA post intervention. Although the latter study mentioned is not completely comparable with the present study due to the method and

reporting of PA, it still highlights and supports the positive effects of interventions on PA levels in children. On the contrary, Cliff et al., (2007) reported an overall decrease of 18% of time spent in MVPA. It was explained that the decrease was due to a ceiling effect (novelty of using new equipment) and that baseline measures were 20% higher than the average for children that age in the area (Cliff et al., 2007). There are limited studies that have reported PA data alongside an intervention for FMS, however when they have, such as these two aforementioned studies, it has been MVPA that has been reported. Conversely, Westerterp and Plasqui (2004) have highlighted that it is activities of low and high intensity that are the main contributors to a child's PA level. Therefore, by measuring their habitual PA level, like the current study, it includes all levels of intensity that will contribute to a child's PA status. This allows for the results to provide a better indication of the overall effect that an increase in FMS will have on habitual PA, which has been highlighted to be important to health (Westerterp and Plasqui, 2004).

Consistent with previous research, children were more active on weekdays compared to weekend days (Riddoch et al., 2004; Rowlands et al., 2008). Although the average weekend steps significantly increased the most (66%), the amount of average weekend day steps was still not as large as the average weekday steps (14865 steps compared to 15491 steps, respectively). Due to the intervention being part of the school day it would have been interesting to see if this increase in weekday steps came from during or after school activities. Mota et al., (2003) conducted a study which reported that girls PA in the weekdays were made up from the school day

whereas a boy's PA is made up from afterschool activities. If this was assessed in the current study, then the effect of the intervention on PA could have been more specific. Unfortunately it was not possible to collect this information in the current study due to school constraints. However, some may argue that, although this information might be interesting, one of the main aims of the intervention was to increase PA, which was successful. The control group increased their PA levels, however this was not significant. This supports the argument that the intervention group's increase in PA was due to the intervention itself and supports the hypothesis.

As stated PA is significantly higher post intervention and although PA was still significant higher in the six week follow up compared to baseline, PA had significantly decreased from the post intervention measure. From the post intervention measure to the six week follow up the ADS decreased by 3114 steps. If ADS kept decreasing at this rate in another six weeks ADS would be lower than the baseline measure. Therefore, this questions whether the rise in PA was an intervention effect and will PA just revert to back to original levels. Further follow up assessments would have beneficial to identify if PA did revert to back to normal or if they did stay higher compared to baseline. Bryant et al., (2014) reported that FMS mastery is associated with PA levels one year later. Therefore, it might be that there is a time delay between gaining mastery in FMS and it influencing PA levels. However, Bryant et al., (2014) only conducted a one year follow up, so it may be that it is a different amount of time needed for mastery in FMS to be associated with PA levels.

### 6.6.4 Changes in PA for boys and girls separately

Both girls and boys increased similar amounts in the post intervention for average daily steps and average weekday steps. However, for weekend steps girls increased by 9% more than boys did. In the six week follow up, girls weekend steps decreased by 38% compared to boys increasing by 9% (Figures 6.6 and 6.9). As mentioned, there is sparse data on the effect of FMS interventions on PA levels and from this literature there is limited data reporting differences between genders. Fairclough et al., (2013) reported that there was no intervention effect on PA level, but did report that it was more beneficial to girls and suggested this was because they were less active at baseline. This would explain the immediate rise in girls compared to boys for the present study. Although the girls decrease by the follow up, they are still significantly more active than baseline, suggesting that the intervention is still effective for both boys and girls. As stated above if both boys and girls keep decreasing steps at the same rate as they did in the follow up, in another six weeks they would revert back to their original level.

### 6.6.5 Changes in weight status

Descriptive statistics were provided for the weight status data, due to the short duration of the intervention weight status was not likely to significantly change, which was also the case for similar research of this kind (Cliff et al., 2007; Graf et al., 2008; Fairclough et al., 2013). Although BMI in the six week follow up decreases, the z score increases. By using z scores, it takes into account their sex and age. To a non-expert a decrease in BMI may

be thought to be positive, however an increase in z score indicates that children are becoming further away from a normal weight, thus highlighting the importance of using z scores to identify the relevance of the change. BF% for the intervention group stays the same. BMI z score increases but the number of children classed as overweight/obese decreases. Over the 12 weeks children will grow and become heavier, however, by reporting that BF% does not change the increase in BMI and the change in BMI z scores must be due to an increase in fat free mass. Research has reported that when adults increase PA, specific strength training/plyometric training will result in an increase of muscle mass (Yarasheski et al., 1993; Fiatarone et al., 1994). The present intervention did feature plyometric aspects, that could potentially cause an increase in muscle mass (fat free mass). However, strength training studies in children that have all lasted more than eight weeks did not report any increase in muscle mass (Weltman et al., 1986; Siegel et al, 1989; Faigenbaum et al., 2009). This highlights the importance of measuring BF% alongside BMI.  Although the control group also decreased the number of children classed as overweight/obese, the control group started with a higher percentage (39% compared to 33%) and the intervention group ended with a lower amount of children classed as overweight/obese (36% compared to 35%).  In contrast to this, Graff et al., (2008) reports an increase in BMI and the number of children classed as overweight/obese (15%-18%) post intervention. Graff et al., (2008) concludes a more intense intervention is needed to see positive effects on weight status. Similarly to the present study Fairclough et al., (2013) reports an initial increase in BMI z scores but then decreases to lower than the

baseline in the follow up study. However, this intervention is six weeks and not of high intensity (one hour a week). Therefore, you would not expect to see a weight change over this short period of time (Graff et al., 2008).

### 6.6.6 Changes in weight status for boys and girls separately

Girls were the only group to progressively decrease in the number of children classed as overweight/obese at each measurement stage. Similarly Fairclough et al., (2013) identified that interventions had a more positive effect on the weight status of girls compared to boys. Both the present study and Fairclough et al., (2013) both report that boys are more physically active and the percentage of overweight and obese is higher in girls compared to boys. Therefore, there is more opportunity for girls to increase their PA which should have a direct effect on their weight status in the longer term. The changes in weight status across the intervention are limited by the length of the study and research suggests that children need to have a sustained increased level of PA participation to increase motor competence to influence a positive weight change (Vandorpe et al., 2011).

### 6.6.7 Changes in Self Perception Scores

PPCSC scores significantly increased from baseline to post intervention and were then maintained in the six week follow up. Previous research has suggested that children who have a higher self-perception are more likely to have better FMS competency (Southall et al., 2004; Stein et

al., 2006; Hands et al., 2010; Jones et al., 2010). Ekeland et al., (2004) completed a systematic review on exercise/PA and self-esteem in children and concluded that exercise has positive short term effects on self-esteem. Authors also identified that no studies conducted follow up data to distinguish and long term effects. The current study makes an important contribution to the literature as it conducts a follow up assessment and identified that physical self-perception (self-esteem) remains significantly higher than the baseline measurement, along with FMS and PA level. Previous studies that have assessed the relationship between physical self-perception and PA have used a variety of methods such as; physical activity only, some physical activity plus skills training and counselling and some used high intensity exercise and strength training. The current study used PA and skills training in one PE lesson and highlighted that this method had a significant positive effect on physical self-perception post and six weeks after the intervention. Whilst these studies have identified this relationship between the two variables, the cause and effect relationship has still remained unanswered. It could be that if children perceive themselves as being more competent, in turn perceiving tasks as being easier, they then spend more time participating in PA, resulting in an increase in ACM (Goodway and Rudisill, 1997; Weiss and Amorose, 2005). Or on the other hand, do children who spend more time in PA allow themselves to develop these skills, thus increasing their PMC due to a higher AMC. Bois et al., (2005) has reported that a child's physical self-perception is directly influenced by their parent's perceptions of them. Also, Biddle and Matrie (2007) have suggested to theories of the relationship between physical self-perception and PA. The

first being the 'motivational approach' or 'personal development hypothesis' this explains that children with higher self-esteem (physical self-perception) are more likely to engage in PA to enhance their self-worth. The second is the 'skill development hypothesis' this suggests that self-esteem (physical self-perception) is modified throughout experiences and is a product of PA or exercise. Biddle and Matrie (2007) report that initial uptake in PA may need to be externally motivated, which will then enhance self-esteem or physical self-perception. By mastering FMS, this will prepare the children to have the skill set for the initial up take of PA to start the positive relationship between the latter and physical self-esteem/perception.

Similar to the PA results, the PPCSC scores at six week follow up were significantly higher compared to baseline, but the scores had decreased from the post intervention measurement. Therefore, these findings question whether the PPCSC scores would just revert back to original levels in further follow up assessments. Once children have mastery of a skill they cannot lose it and according to Stodden et al., (2008) the age of the children in this study should be able to accurately perceive their AMC. Therefore, with the number of children who have gained mastery of the FMS the PPCSC score should not revert back to its original score (Stodden et al., 2008). However, if it were to then it would challenge Stodden et al's (2008) conceptual model. Again, further follow up assessments are needed for these conclusions to be made.

### 6.6.8 Conclusion

This study trialled modifying the content of one out of two statutory PE lessons that the children have per week. This intervention can conclude that by focussing one PE lesson on the development of FMS (one hour a week for six weeks) it will have a positive benefit on PA level, weight status and physical self-perception. The ultimate aim of PE is to provide children with the skills needed to lead an active lifestyle outside of school and in the future (QCA, 2007). Therefore, the current intervention offering what the existing statutory PE does not (providing children with the skills to lead an active lifestyle, British Heart Foundation, 2009; Lubans et a., 2010; Bryant et al., 2013). Although, further research is required to assess any presence of a dose response gained from the modified PE lesson. For example, would it be even more beneficial conducting it twice a week? The effects of this intervention can only be generalised to doing the intervention within the school day. Further follow up assessments need to be conducted to understand the lasting effects of the intervention on the measured variables.

The limitations of this study are discussed in the section 7.2 (Strengths and limitations).

## 7.0 Overall discussion

Study 1 identified, unlike previous literature (Hands et al., 2008), that there was not a graded increase in FMS mastery as children got older. In the analysis of children in Years 2 to 6 it was reported that Year 4 (8-9 years) children had lower mastery level of locomotor skills than other ages reported, and Year 5 (9-10 years) children had higher object control skills than other ages reported. A few explanations are discussed in study 1 as to why these year groups have lower mastery levels compared to other year groups. For example, it could be due to the neuromuscular development of the children not occurring at the same rate of growth (McMorris, 2004; Lenroot and Giedd, 2006) or the teaching quality of PE that the children receive. From just assessing children in one school it is not possible to conclude the exact reason for these inconsistencies in FMS mastery or to ascertain whether these changes are likely to be consistent across schools containing similar children. Other research is equivocal for understanding why these changes have happened; research has both agreed (Lopes et al., 2011) and disagreed (Hands et al., 2007) with the findings from study 1. However, study 3 (the intervention) also completed research on children in Year 4 and Year 5, which were the ages that exposed the ungraded response. In study 3, both Year 4 and 5 children showed lower mastery in object control skills (throw and kick) and the jump compared to the rest of the FMS, this is inconsistent with study 1 which reported the locomotor skills as having the lowest mastery. Also inconsistent with study 1, study 3 showed a decrease from Years 4 to 5 in the mastery of the sprint run. Study 1 and 3 were

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completed on the same aged children, from the same area in Coventry with the same Socio-Economic Status. With these two aforementioned studies having conflicting results regarding the graded FMS response with age it can be concluded that an ungraded response to FMS is unlikely to be as a result of neuromuscular development but more likely due to the inconsistency in quality of the PE teachers and content of the PE lessons.

Study 2 identified an association between mastery levels in FMS and future PA participation. Research has identified a link between PA level, cognitive function and academic achievement (Donnelly et al., 2009; Fox et al., 2010; Kantomaa et al., 2010; Howie and Pate, 2012). A protein that underpins cognition in the brain is the Brain Derived Neurotropic Factor (BDNF) (Go´mez-Pinilla et al., 2002; Molteni et al., 2002; Vaynman et al., 2003). Research has reported that a sustained level of exercise/PA can increase the expression of genes that encode for BDNF (Neeper et al., 1995; Carro et al., 2003; Van Hoomissen et al., 2003). An increased cognitive function has been associated with improvements in attention, memory and Intelligence Quotient (IQ) which have all been associated with academic achievement (Howie and Pates, 2012). Therefore, an increase in PA can positively influence academic achievement. Study 2 has identified that mastery in FMS in primary school is associated with PA participation. No research has been conducted to identify if there is a direct link between FMS and academic achievement. However, Howie and Pate (2012) produced a model (Figure 7.1) to identify the mechanisms between PA, cognitive function and academic achievement. This model could be adapted to explain a potential indirect link between FMS and academic achievement (Figure

7.2). This could be a potentially important link to highlight the importance of FMS mastery in children to their class teachers. Teachers and schools are assessed on their Ofsted reports and one of the main components they are assessed on is academic achievement. Therefore, if teachers could understand that by teaching FMS in the correct way and ensuring that children have mastery of the skills, it would influence PA and feed into Howie and Pate's (2012) model, shown in figure 7.2, and then those teachers might be more likely to engage and promote improving FMS mastery in children.
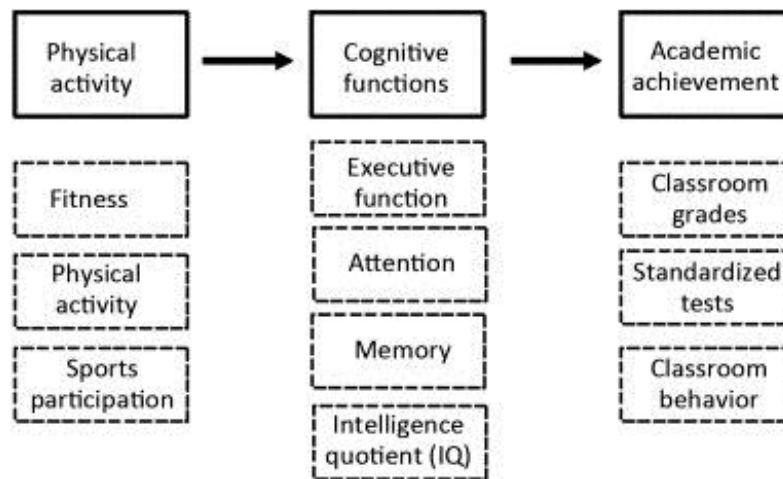


Figure 7.1 Howie and Pates (2012) model to explain the relationship of physical activity, cognitive functions, and academic achievement as defined for this review
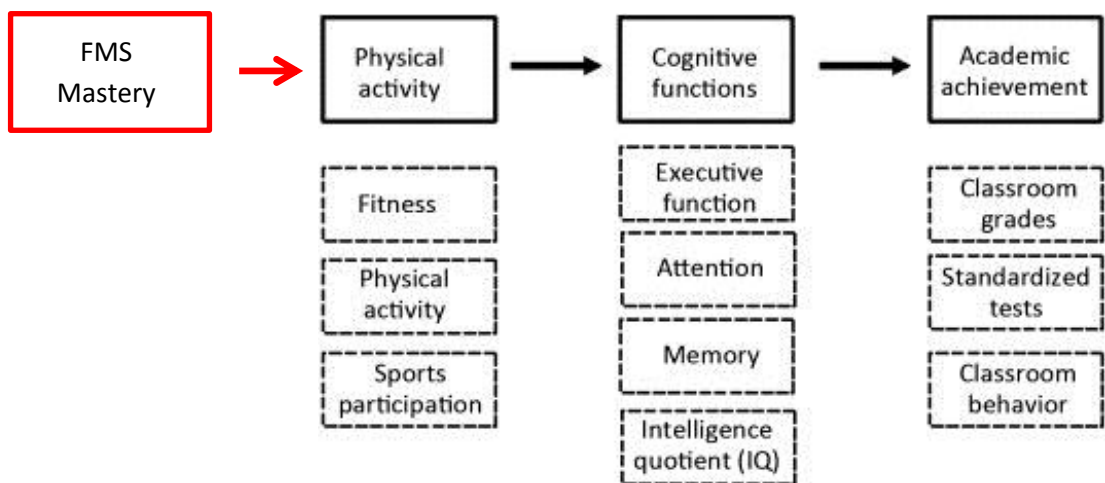
Figure 7.2 Modified version of Howie and Pates (2012) model to explain the relationship of FMS, physical activity, cognitive functions, and academic achievement.


In study 2 it was reported that a combination of previous FMS and current FMS predicted the highest amount of variation in PA levels. However, the intervention reported in study 3 found that there was an immediate increase in FMS and PA. The results from study 2 would have suggested that this increase in FMS would have had a delayed effect on PA level. In study 2 only a one year follow up was conducted which identified prediction of the variation in PA one year later from when the FMS had been recorded. Due to only one follow up data collection conducted it is not possible to quantify the exact delay in which PA will become a consequence of FMS mastery. The intervention did conduct a six week follow up which still showed a significant increase in PA, although this was lower than when assessed immediately post intervention. Study 2 and 3 cannot be compared in regards

to the association between FMS and PA. The children in study 2 had not had any form of specialist FMS programs and had just been subject to their normal PE lessons. Whereas in study 3, the children had been through a six week FMS program as a result of which more children gained mastery of the FMS, and children initially increased their PA. Primarily this provides more evidence between FMS and PA levels. In the six week follow up PA levels started to decrease and if this continued at the same rate in a further six weeks PA levels would have reverted back to original levels. Further follow up assessments are needed to understand the lasting effects of FMS interventions on PA level. Furthermore, if these longer follow up assessments were conducted from intervention studies and similar statistical analysis could be completed as seen in study 2, then conclusions could be made between the effect of FMS programs in association with current and future PA levels. This would then give information on whether a gain in FMS mastery through an intervention can be associated with PA levels or whether children must have a natural ability to complete the skills which consequently allows them to be more physically active.

Study 3 reports that the hop and gallop in girls and sprint speed in boys was significantly important in the prediction of PA levels. This is unlike Barnett et al., (2008) and Okely et al., (2001) who also predicted small variation in PA but they do not report which skills significantly contribute to the model and were therefore unable to conclude whether certain skills were more important in PA participation. Therefore, elucidating the importance of reporting individual skills as this would enable identification of which skills may need more time spent in teaching of them. Some research has not

reported individual FMS score but just given an overall score (Cliff et al., 2007; Lopes et al., 2011; Vandrope et al., 2011). This proposes two problems, firstly authors cannot identify individual skills which may need to be focused upon, and secondly it does not allow any gender bias between skills to be exposed. In contrast to these studies, Mitchell et al., (2011) highlighted the weaker skills in the pre-tests that the children possessed and concentrated on mastering them throughout an intervention. The results from study 2 would support this as it identified that some skills (hop and gallop for girls and sprint speed for boys) are better predictors of PA participation than others, concluding that mastery in certain skills may be more important to enable PA. It could then be argued that you need mastery of all FMS to give children a wider option of what physical activities they may like to participate in. If different skills were singled out for focus then gender differences in FMS mastery would need to be controlled for. Study 1 reported gender bias for certain skills and study 2 reports different skills being important for PA participation. However, study 3 concludes that a broad intervention will increase, to a similar amount, the percentage of boys and girls who reached mastery of the six skills. In addition by keeping the intervention broad it allows every child to improve on every skill, rather than the skills that the majority of children need to improve on. Although gender socialisation will most likely always occur, at least if children can master all FMS it will give them the opportunity to partake in a wider range of activities and increase their self-perception to increase motivation to stay in an activity (Southall et al., 2004; Stein et al., 2006; Hands et al., 2010; Jones et al., 2010). This is with hope that in future research the gender bias will be removed from

literature when investigating FMS in boys and girls (Okely and Booth, 2004; Jones et al., 2010; Vandaele et al., 2011).

In Study 1, the objective and subjective measurement of the run showed a significant negative correlation, identifying that the better the technique of the skill the faster the children would run. However, the intervention in study 3, the number of children who had mastery or near mastery of the run increased post intervention, whilst the sprint speed got slower by 0.4%. This emphasizes the need to teach children the correct technique of the skills at an early age so they do not have to be retaught the skill and do not have to wait longer for it to become autonomous with the objective measurement suffering as a consequence (Fitts and Posner, 1967). Though, this was not the case for the jump and jump height as both improved post intervention. The subjective technique that was taught for the jump is the same technique to maximise the jump height. This was not the case with regards to the sprint run. The subjective technique of the sprint run that was taught was the technique of how to run fast when the child is at full speed. The sprint run was assessed over a 10m distance, which would be purely acceleration and thus not performing the correct technique of the sprint run. Therefore, explaining why there was only an increase by 3.3% increase in the number of children who gained mastery of the run post intervention and why there was not a consistent increase in the objective and subjective measure of the sprint run.

When children participate in sport or PA they will continue to do so according to their enjoyment, which often comes from success from increased skill level to maintain their motivation (Weiss, 2013). In the

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children's eye, the success will be down to the objective result of the skill; for example if a child can throw further then they will be able to field successfully in rounders. Although the correct technique of the throw would underpin the distance of the throw, it is unlikely that children would understand this and have the motivation to persist practicing the new technique of the skill until it became autonomous and an improvement in the objective measurement was observed. This therefore highlights the importance of PE teachers teaching children the correct movement patterns from a young age to maximise PA participation to maintain a healthy weight status.

From all three studies the importance of teaching FMS correctly from an early age has been concluded. It has also been established that it is possible to increase FMS mastery in children through an intervention. This leads us to question which would be the most effective method to teach children the FMS. Traditionally, it is thought that the learning of a motor skill relies on working memory and once the skill has been repeated enough it will become autonomous and removed from the working memory control (Alloway and Gathercole, 2006). This is a form of explicit learning (Fairbrother, 2010). The intervention in study 3 included explicit learning by using a circuit based session which involved repeating the same movement patterns. It is thought that working memory has a capacity and learning can be inhibited by this capacity (Alloway and Gathercole, 2006). In conjunction with the circuits that were used, children also learnt moves to 'up to date' popular songs. Unknown to the children they were actually learning some of the FMS. Out of all eight FMS the four skills that improved the most throughout the intervention were the skills that were taught via the method of

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song. This is a form of implicit learning, where children are not conscious that they are learning a skill and therefore they are not using up the capacity of their working memory. The reason why children improved more in the skills that were learnt to songs could be a result of the intensity of that activity. The circuits were timed and the children completed them at their own pace and therefore would not have to push themselves to a higher intensity. However, when completing the moves to the songs, the children would have to keep up with the movement patterns to the music and have no choice but to increase the intensity they were working at. When skills are completed at a higher intensity the degrees of freedom are reduced and skills are developed (Berthouze and Lingarella 2004). Therefore, the reason why the skills that improved the most that were conducted to music could be down to the intensity of it and not the rhythm. However, intensity measures were not taken throughout the intervention and further research would need to test this speculation.

In a holistic view of all the findings from this research and when considered in the context of Stodden et al's (2008) model the results develop and extend this model and offer further understanding of the underlying mechanisms of this topic in a unique way. Stodden et al's (2008) model explains that motor competence, PA level and weight status are a systematic chain of events. However there is no consideration for a time delay between these variables in the development of a child. Results from study 2 indicate that a combination of prior FMS mastery and current FMS mastery contribute to the prediction of the variance in PA. Therefore to develop the model an extra arrow (highlighted in red) has been added to the model to identify and

display an understanding that this is not solely a direct consequence (Figure 7.3).
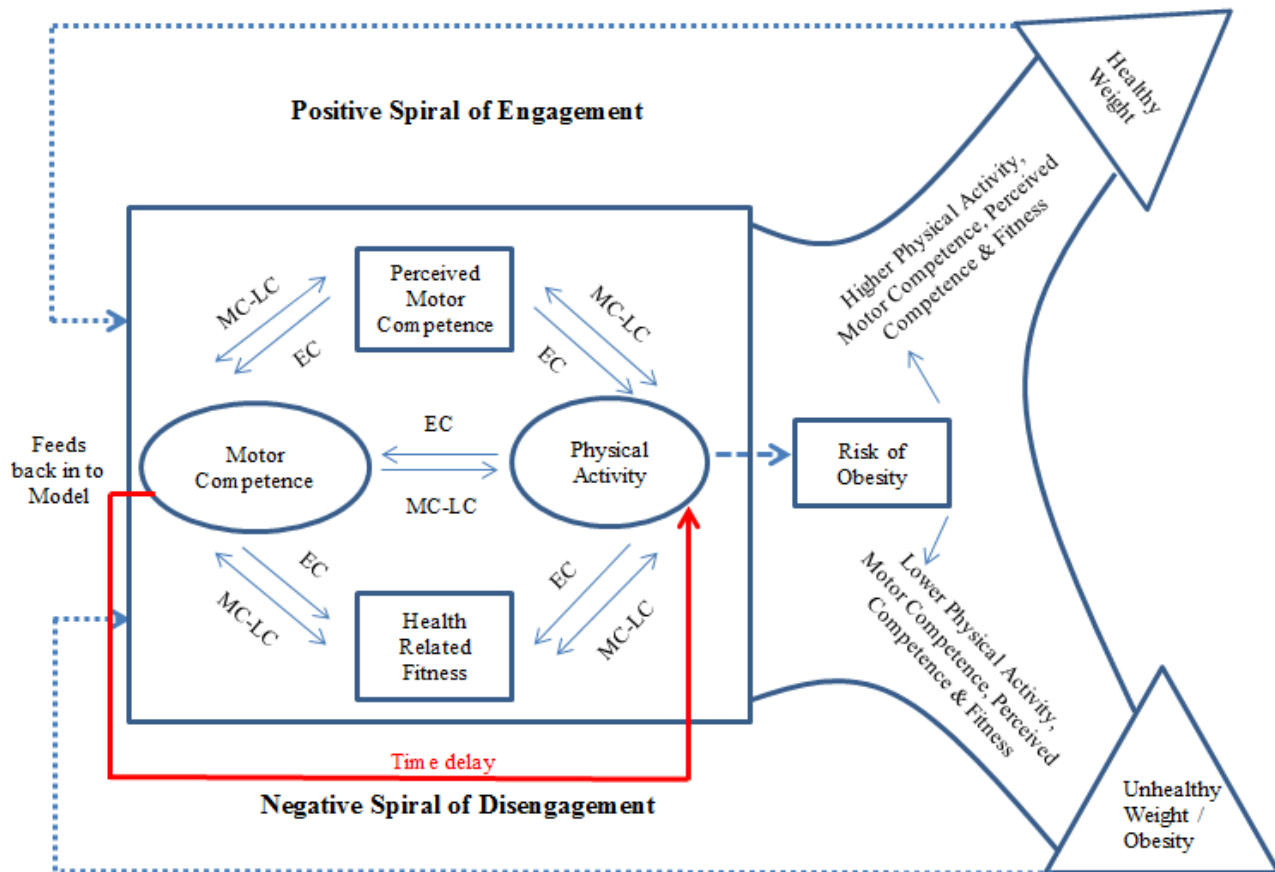


Figure 7.3 A development of Stodden et al's (2008) conceptual model.

As stated the relationship between these variables are multi mechanised and interactions between the variables do not systematically flow as Stodden et al., (2008) originally proposed. The results from the research throughout this thesis support the model but also help develop it further in a unique way by taking time in to consideration. The time delay that has been added to this model has been developed from the results reported in study 2. Study 2 investigated a time delay of one year to understand the relationship between previous and current FMS with PA levels. The fact that

more variance in PA was predicted from a combination of prior and current FMS mastery suggests there is some sort of time delay. However, there is no evidence to suggest that it is exactly a year for this association to be displayed. Study 2 only assessed one time point (one year later) and there is no evidence to suggest that this time delay is neither longer nor shorter than a year. Therefore, for the foreseeable future the addition of the arrow must state a time delay that has not been quantified until future work can determine this.

## 7.1 Practical implications of the research

The results from the research in this thesis lead to some future recommendations. Firstly, the results from study 1 highlight that there are large numbers of children who do not have mastery of the eight FMS. Thus, recommending that FMS needs more of a focus in primary schools. In addition, Study 2 identified an association between mastery levels in FMS and future PA participation. It is recommended that results such as these should be used to influence primary school PE policy in the UK, to ensure that programmes are in place not only to teach the FMS but to monitor the progression of the children's FMS development. Children are taught England's national curriculum for primary schools that comprises of 172 pages dedicated to English, Maths and Science which includes targets for each year of the two key stages with information on what exactly needs to be taught and how. In comparison to this P.E only have three pages with very limited information (Department for Education, 2013). It states that FMS needs to be mastered, but gives no information on targets for the mastery of these skills. To become a primary school teacher you need to complete a primary PGCE. Throughout this course it mainly focuses on the teaching of the core subjects (English, Maths and Science) with significantly less time spent on other subjects, including PE. An example from the University of Hull who run a one year Primary PGCE, only spend two days of the whole degree, on the teaching of PE, of which they are taught how to teach activities such as gymnastics, games, dance, athletic activities, outdoor and adventure activities (University of Hull, 2013). However, to have success in

performing these gross motor skills and sporting activities children must have mastery of the FMS first (Gallahue and Ozmun, 2002). If teachers are not being directed, or given the knowledge, that it is these FMS that need to be mastered first and how to do this, then it would explain the inconsistency in mastery level throughout primary school that was highlighted throughout the studies in this thesis. Teachers need to be trained to understand the importance that FMS has on a child's future PA level and how to teach children to master these skills.

Study 3's results suggests that by conducting broad interventions at an early age and allowing both girls and boys to develop all FMS it may help minimise children being socialised in to gender specific activities (Blakemore and Renee, 2005). In addition to this it may be argued that the skills performed to the songs are easier to master and that is why a higher improvement was demonstrated. However, three of the four skills that were performed to music are locomotor skills which previous research identified as being the hardest to master (Westerndorp et al., 2011). This finding from study 3 is novel and should be taken into consideration for the teaching of FMS in the early stages of primary school

## 7.2 Strengths and limitations

A strength from the research in this thesis is that multiple schools were used throughout all three experimental studies which increased the applicability of the results to a broader population. Study 1 used BMI as a measure of weight status, which as mentioned holds its own limitations

(Nevill et al., 2006). A particular strength of the research is that this limitation of the use of BMI was taken into consideration in studies 2 and 3, resulting in the use of BF% in conjunction with BMI. It was important to still include BMI as it is the method to classify weight status that is recommended by the International Obesity Task Force (IOTF).Furthermore, in the UK it is the method by which government assesses weight status in children and is the most widely used tool to determine weight status. Additionally, BMI is the method most commonly used in other literature (Erwin and Castelli, 2008; Okley et al., 2004; Graf et al., 2004; Southall et al., 2004; Cliff, et al., 2009; D'Hondt et al., 2009) and its use makes this current research comparable with such previous studies. In study 2 and 3 BMI and BF% were both used to classify weight status and both methods produced very similar results. Therefore, this increases the strength of the use of BMI in study 1 and the literature.

Identifying habitual PA in children was the aim of studies 2 and 3, an additional strength of this research is the appropriate method chosen to assess this by the use of pedometers (Clemes and Biddle, 2013). Although children can be unreliable in wearing pedometers for the required amount of time this was limitation was minimised by the use of diaries to record, with their parents, when they did not wear the pedometer. Only children with four full days of data were included in the analysis and children who had values <1000 steps or >40,000 steps per day were excluded from the analysis (Rowe et al., 2004; Clemes and Biddle, 2013). By attempting to control for the limitations of the pedometery methods elucidates strengths and reliability of results throughout this research.

An additional methodological limitation was some of the components included in the POC. For example, when assessing the balance skill one of the components is 'non-support leg bent'. There is no specific angle requirement for this and is down to the assessor's digression. For most of the skill components very specific guidelines were given, including joint angles in the kick and run. To overcome this limitation, inter and intra reliability measures were conducted to ensure consistency and reliability of the results. Furthermore, out of the different process orient measures that are within literature to assess FMS (discussed in section 2.1) the POC has additional components and they are more specific. Therefore, this increased the reliability of this chosen method.

The predominant limitation in study 1 was the cross sectional design. The explanation of why different year groups displayed differing mastery levels was speculative due to the cross sectional nature of the study. If longitudinal data was collected then conclusions could have been made on whether this was due to individual differences or the effect of having different class teachers taking PE lessons. In study 1 age is categorised by using Year group. By categorising the children into year groups it assumes that all the children are the same age, when in fact there could be up to twelve months between two children in the same year group. If exact age was used then perhaps these difference in mastery levels between the age brackets of using year group may have been eliminated.

In study 2 the main limitation was the design of this study by not having a PA assessment at baseline. If PA data were available in the first year of measurement (baseline) then analysis would have been able to

identify how much FMS influences current and future PA and the cause and effect relationship could have been concluded. Also, delta values for PA could have been calculated and analysed highlight magnitude of change in relation to the change in FMS levels.

Study 2 only conducted a follow up at one time point. Therefore, it can only be concluded that variance in PA is associated with current FMS levels and FMS levels from one year previous. However, if shorter and longer FMS follow up assessments were conducted then more precise conclusions could have been made about the delay in the association between FMS mastery and PA level.

A key limitation in the intervention in study 3, was the use of the control group from the same year group and school as the intervention group. It was speculated that the reason for the increase in the percentage of children classed as having mastery was due to the children in the intervention group teaching the control group in the playground. If a control group in a different school was used, the true effect of the intervention would have been reported.

A major limitation from the intervention was not having the measurement of intensity. A target for PE is that children spend 50% of their lesson at MVPA (NICE, 2009). To achieve this teachers often use team games to increase the intensity of the session (Fairclough, 2003; Warburton and Woods, 1996). There are some arguments that children should have lower intensity lessons that concentrate on the teaching of the FMS for long term benefits. If both aims could be met in one PE lesson then the benefits to

the children would be increased. Unfortunately this conclusion was not able to be made as a measure of intensity was not collected during the intervention.

After the intervention only one six week follow up was conducted. It would have been useful to have further follow up measures conducted to determine any lasting effects of the intervention or whether the changes seen in the variables measured were due to a one off intervention effect. Specifically, in the six week follow up that was conducted PA levels started to decrease and if they continued to decrease at the same rate in another six weeks they would have reverted back to their original levels. Therefore, if further follow up measurements were made more accurate conclusions about the effectiveness of the intervention could be made. If a year follow up was conducted then the conclusion made from study two could have been tested (a combination of previous and current FMS level if associated with PA level).

Throughout the thesis eight FMS were measured subjectively. Only two skills were measured objectively, the sprint run and the jump. The reason why just these two skills were measured objectively is explained in chapter 2.2. For the skills where the objective outcome could play an important part in the success of PA and sport it may have been of benefit to measure these (catch, throw, kick, balance). This would have been particular interest in study 2, to determine if the subjective measure or the objective measure predicted more variance in PA levels. It would also have been interesting to see if changes in the two measures correlated. Study 1 reports a significant correlation between the subjective and objective measures,

however these are very weak and further work should determine which method of measuring FMS is the most important. Although, research has identified that it is the technique of the skill that is associated with an increased PA and a lower weight status (Okley et al., 2001; Okley et al., 2004; Hamstra-Wright et al., 2006 McKenzie et al., 2002; Fisher et al., 2005; Barnett et al., 2009; Cliff et al., 2009; D'Hondt et al., 2009), therefore justifying the main use of the subjective measure.

As stated above, only eight FMS were measured subjectively throughout this research, yet there is a multitude of other FMS that could have potentially been used to contribute to the predictive models. If other FMS were found to be better predictors to PA then this would be important information not only to PE teachers and policy, but to influence future interventions that aim to increase PA.

After three weeks of the intervention the children were progressed on to allow them to perform the skills in different or competitive situation. All children were progressed on together. The children were not reassessed to identify if they had gained mastery in the skills to highlight if they should be progressed on to the next stage. If children did not have mastery and were progressed to early then it could hinder their learning. The assessment of FMS is a timely process and would not be realistic for teachers to carry out regularly. If this were possible and only children who had gained mastery of the skills progressed on to the next stage, this could have hindered the children's physical self-perception which is important to maintain motivation to keep participation (Stodden et al., 2008).

## 8.0 Future research

Results presented in this thesis have highlighted some novel findings regarding FMS, PA and weight status in children. Results have indicated that the increasing high rates of obesity that are seen in the UK could be reduced via mastery of FMS to aid PA participation level. This thesis has identified that by replacing one of two statutory PE lessons with a focus on the development of FMS it can have positive benefits on FMS mastery, PA, weight status and physical self-perception. However, a dose response is unknown to this and future research should trial different variations of the FITT (Frequency, Intensity, Time, and Type) principles, particularly intensity, to identify the most effective method to teach the FMS to maximise the positive long term benefits.

In addition to trialling the FITT principles, future work should focus on different methods of teaching or developing FMS. Results in study 3 indicate that FMS taught via an implicit learning style could potentially be more effective. This conclusion needs to be researched further to validate this finding. The most appropriate method to assess this would be to conduct multiple interventions throughout multiple schools with the use of control schools. Interventions should include an implicit and explicit learning group to identify if one method will significantly improve FMS more than the other. PA, weight status and physical self-perception should be assessed to identify if either technique shows stronger positive relationship with these variables. If one method were to be highlighted as more beneficial than this should be taken in to account by PE policy and implemented into the curriculum.

Furthermore, research needs to be conducted to identify target ages that particular FMS needs to be mastered by to gain the health enhancing PA. Initially this could be done by recording baseline measure of FMS and PA at different ages and then identify the children who meet the recommended guidelines of PA, assess their mastery and identify if this mastery is higher than those children who do not meet the recommended guidelines for PA. Once these targets at different ages have been established they could be worked in to the curriculum for PE and assessment tools should be provided. This will allow teachers to identify children who may need extra assistance with mastering the FMS and ensure that all children are getting the coaching they need to maximise their opportunity to partake in PA.

Study 2 identified that some FMS are associated with PA levels more than other FMS; however this finding needs further research to test this in detail. An option for how to do this would be to conduct multiple interventions that only focussed on increasing mastery in certain skills with the assessment on PA level in the children. It could then be identified whether an increase of mastery in a particular skill would significantly increase PA levels more than mastery of other skills. Findings from this study would be extremely important for primary school teachers as there is limited time for PE and if research could identify the importance of specific skills then PE lessons could be optimised.

From the proposed future research, resource packs could be produced for multiple use; PGCE training degrees and current primary school teachers to ensure that all teachers are trained to understand the

importance of children mastering the FMS and to be able to teach and analyse FMS mastery in children. Resource packs would include information on the optimal methods to teach FMS, assessment and analysis tools, guidelines for mastery levels for each age/Year group and example lessons. If this resource pack could be produced then children would be in a much better position to learn the FMS needed to maximise PA participation and maintain a healthy weight status. However, the link between FMS, PA and weight status still needs to be developed further before this can be done.

## 9.0 Conclusions

Mastery of FMS is not obtained by a large proportion of children by the age that other research has suggested. A combination of mastery of prior and current FMS is associated with current PA levels. The results from this thesis have established that it is possible to increase FMS mastery level via changing the content of one PE lesson a week, which has immediate positive effects on habitual PA, weight status and physical self-perception.

Results from this thesis should be used to influence PE curriculum and policy in the UK, to give teachers further training and guidance on how important FMS mastery is, including the potential beneficial effects on PA and weight status.

# 10. References

Abbott, B. D. and Barber, B. L. (2011) 'Differences in Functional and Aesthetic Body Image between Sedentary Girls and Girls Involved in Sports and Physical Activity: Does Sport Type make a Difference?' *Psychology of Sport and Exercise* 12, 333-342

ACARA, Australian Curriculum, Assessment and Reporting Authority (2011) [online] available from <http://www.acara.edu.au/curriculum/curriculum.html> [01/27/2013]

Adams (1971) 'A Closed Loop Theory of Motor Learning'. *Journal of Behaviour* 3, 111-149

Aiyagari, V. and Gorelick, P. B. (2011) *Hypertension and Stroke: Pathophysiology and Management.* New York, USA: Humana Press

Alderson, J. and Crutchley, D. (1990) *New Directions in Physical Education.* Champaign: IL, USA: Human Kinetics

Alloway, T. P and Gathercole, S. E. (2006) *Working Memory and Nuerodevelopment Disorders.* Sussex, UK: Psychology Press

Almond, L. (2012) *Physical Education in Schools.* Second edn. New York, USA: Routledge

Australian Bureau for statistics, Census 2011 (2011) [online] available from. <http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/1> [13/11/14]

Baecke J.A., Burema J. and Frijters J.E. (1982) ' A Short Questionnaire for the Measurement of Habitual Physical Activity in Epidemiological Studies'. *The American Journal of Clinical Nutrition* 36, 936-942

Bakris, G. and Baliga, R. R. (2012) *Hypertension.* New York, USA: Oxford University Press

Baranowski T., Thompson W.O., DuRant R.H., Baranowski J. and Puhl, J. (1993) 'Observations on Physical Activity in Physical Locations: Age, Gender, Ethnicity, and Month Effects'. *Research Quarterly for Exercise and Sport* 64, 127-133

Barbero-Álvarez, J. C., Coutts, A., Granda, J., Barbero-Álvarez, V., and Castagna, C. (2010) 'The Validity and Reliability of a Global Positioning Satellite System Device to Assess Speed and Repeated Sprint Ability (RSA) in Athletes'. *Journal of Science and Medicine in Sport* 13, 232-235

Barnett, L M., Van Beurden, E., Morgan, P.J., Brooks, L.O and Beard, J.R. (2009) 'Chilhood Motor Skill Proficiency as a Predictor of Adolescent Physical Activity'. *Journal of Adolescent Health* 44, 252-259

Barnett, L. M., Morgan, P. J., van Beurden, E., and Beard, J. R. (2008) 'Perceived Sports Competence Mediates the Relationship between Childhood Motor Skill Proficiency and Adolescent Physical Activity and Fitness: A Longitudinal Assessment'. *International Journal of Behavioral Nutrition and Physical Activity* 5, 1-12

Baskit, C., Kalkavan, A., Yamaner, F., Sahin, S., and Gullu, A. (2011) ' Investigation of Basic Motor Skills According to TGMD-2 Test on Male Athletes of 10 Ages Group Who Participated to Competitions in Individual, Team and Racket Sports Branches'. *Procedia - Social and Behavioral Sciences* 28, 421-425

Bernstein, N. (1967). *The coordination and regulation of movements*. Oxford: Pergamon

Berthouze, L. and Lungarella, M. (2004) 'Motor Skill Acquisition Under Environmental Perturbations: On the Necessity of Alternate Freezing and Freeing of Degrees of Freedom' *International Society for Adaptive Behaviour* 12, 47-64

Beurden, E. V., Barnett, L. M., Zask, A., Dietrich, U. C., Brooks, L. O., and Beard, J. (2003) 'Can we Skill and Activate Children through Primary School Physical Education Lessons? Move it Groove it"—a Collaborative Health Promotion Intervention'. *Preventive Medicine* 36, 493-501

Biddle, S. J. H. and Mutrie, N. (2007) *Psychology of Physical Activity*. London: UK: Routledge

Biddle, S., Sallis, J.F. and Cavill, N. (1998) *Young and Active? Young People and Health-Enhancing Physical Activity - Evidence and Implications*. London, UK: Health Education Authority

Black., T. R. (1999) *Doing Quantitative Research in the Social Sciences: An Integrated Approach to Research Design, Measurement and Statistics.* London, UK: Sage Publications Ltd

Blakemore, J. and Centers, R. (2005) 'Characteristics of Boys' and Girls' Toys'. *Behavioural Science* 53, 619-633

Blatchford, P., Baines, E., and Pellegrini, A. (2003) 'The Social Context of School Playground Games: Sex and Ethnic Differences, and Changes Over Time After Entry to Junior School'. *British Journal of Developmental Psychology* 21, 481-505

Bois, J. E., Sarrazin, P. G., Brustad, R. J., Trouilloud, D. O., and Cury, F. (2005) 'Elementary Schoolchildren's Perceived Competence and

Physical Activity Involvement: The Influence of Parents' Role Modelling Behaviours and Perceptions of their Child's Competence'. *Psychology of Sport and Exercise* 6, 381-397

Branta, C. F. and Haubenstricker, J. (1984) 'Age Changes in Motor Skills During Childhood and Adolescence'. *Exercise and Sport Science Reviews* 12, 467-520

Bray, G. A., DeLany, J. P., Volaufova, J., Harsha, D. W., and Champagne, C. (2002) 'Prediction of Body Fat in 12-y-Old African American and White Children: Evaluation of Methods'. *The American Journal of Clinical Nutrition* 76, 980-990

Breslin, G., Murphy, M., McKee, D., Delaney, B., and Dempster, M. (2012) 'The Effect of Teachers Trained in a Fundamental Movement Skills Programme on children's Self-Perceptions and Motor Competence'. *European Physical Education Review* 18, 114-126

British Heart Foundation (2012) *Couch Kids: The Nation's Future...* London, UK: British Heart Foundation

British Heart Foundation (2012) *Physical Activity Statistics 2012*. London, UK: British Heart Foundation

Brockman, R., Jago, R and Fox, K. R. (2010) 'The Contribution of Active Play to the Physical Activity of Primary School Children'. *Preventive Medicine* 51, 141-147

Bryant, E. S., Duncan, M. J. and Birch, S. L. (2013) 'Fundamental Movement Skills and Weight Status in British Primary School Children'. *European Journal of Sports Science* 14, 730-736

Bryant, E. S., James, R., Birch, S., and Duncan, M. (2014) Does prior or current FMS predict future habitual physical activity (PA) levels and weight status? *Journal of Sports Science* 32, 1775-82

Bureau of Meteorology (2014) Climate statistics for Australian sites [online] available from http://www.bom.gov.au/climate/averages/tables/ca_nsw_names.shtml [13/11/14]

Burke S.M., Shapcott, K.M., Carron, A.V., Bradshaw, M.H. and Estabrooks, P.A. (2010) ' Group Goal Setting and Group Performance in a Physical Activity Context'. *International Journal of Sport and Exercise Science* 8, 245-261

Burkett, B. (2010) *Sports Mechanics for Coaches*. Third edn. Champaign: IL, USA: United Graphics

Burrows, T. L., Martin, R. J., and Collins, C. E. (2010) 'A Systematic Review of the Validity of Dietary Assessment Methods in Children when Compared with the Method of Doubly Labelled Water'. *Journal of the American Dietetic Association* 110, 1501-1510

Burton, A. W. and Miller, D. E. (1998) *Movement skill assessment.* Champaign, IL; Human Kinetics.

Byrne, B.M. (1996) *Measuring self-concept across the life-span: issues and instrumentation.* Psychological Association, Washington, DC: American

Cairnes, R. (1998) *The Making of Development Psychology.* Fifth edn. New York, USA: Wiley

Cairney, J., Hay, J. A., Faught, B. E., and Hawes, R. (2005) 'Developmental Coordination Disorder and Overweight and Obesity in Children Aged 9-14y'. *International Journal of Obesity* 29, 369-372

Carro, E., Trejo, J.L., Nunez, A., Torres-Aleman, I. (2003) 'Brain repair and neuroprotection by serum insulin-like growth factor I'. *Molecular Neurobiology* 27, 153– 62

Carver, A., Timperio, A., Hesketh, K., and Crawford, D. (2010) 'Are Children and Adolescents Less Active if Parents Restrict their Physical Activity and Active Transport due to Perceived Risk?' *Social Science and Medicine* 70, 1799-1805

Carver, A., Timperio, A., and Crawford, D. (2008) 'Playing it Safe: The Influence of Neighbourhood Safety on Children's Physical activity—A Review'. *Health and Place* 14, 217-227

Casartelli, N., Muller, R. and Maffiuletii, A.M. (2010) 'Validity and Reliability of the Myotest Accelerometric System for the Assessment of Vertical Jump Height'. *Journal of Strength and Conditioning Research* 24, 3186-3193

Caspersen, C. J., Powell, K., and Christenson, G. M. (1985) 'Physical Activity, Exercise, and Physical Fitness: Definitions and Distinctions for Health-Related Research.' *Public Health Reports* 100, 136-131

Castelli, D. M. and Valley, J. A. (2007) 'Chapter 3: The Relationship of Physical Fitness and Motor Competence to Physical Activity'. *Journal of Teaching in Physical Education* 26, 358-374

Chen, Z. and Chen, S. Y. (2014) 'When Educational Agents Meet Surrogate Competition: Impacts of Competitive Educational Agents on Students' Motivation and Performance'. *Computers and Education* 75, 274-281

Chinapaw, M. J. M., Mokkink, L. B., Poppel, N. M. N., Mechelen, W. V., and Terwee, C. B. (2010) 'Physical Activity Questionnaires for Youth'. *Sports Medicine* 40, 539-563

Cleland, V., Crawford, D., Baur, L.A., Hume, C., Timperio, A. and Salmon, J. (2008) 'A prospective examination of children's time spent outdoors, objectively measure physically activity and overweight'. *International Journal on* Obesity *32*, 1685-1693

Clemes, S. A. and Biddle, S. J. H. (2013) 'The use of Pedometers for Monitoring Physical Activity in Children and Adolescents: Measurement Considerations'. *Journal of Physical Activity and Health* 10, 249-262

Cliff, D. P., Okely, A. D., Smith, L. M., and McKeen, K. (2009) 'Relationships between Fundamental Movement Skills and Objectively Measured Physical Activity in Preschool Children'. *Pediatric Exercise Science* 21, 436-449

Cliff, D. P., Wilson, A., Okely, A. D., Mickle, K. J., and Steele, J. R. (2007) 'Feasibility of SHARK: A Physical Activity Skill-Development Program for Overweight and Obese Children'. *Journal of Science and Medicine in Sport* 10, 263-267

Cole, T.J., Freeman J.V. and Preece, M.A. (1990) 'Body Mass Index Reference Curves for the UK'. *Archives of Disease in Childhood* 73, 25-29

Cole, T. J., Bellizzi, M. C., Flegal, K. M., and Dietz, W. H. (2000) 'Establishing a Standard Definition for Child Overweight and Obesity Worldwide: International Survey'. *British Medical Journal* 320, 1240-1243

Cooper, A. R., Page A. S., Wheeler, B. W., Hillsdon, M., Griew, P. and Jago, R. (2010) Patterns of GPS measured time outdoors after school and objective physical acitivty in English children: the PEACH project. International Journal of Behaviour Nutrition and Physical Activity, 22, 31-9

Coventry City Council (2012) *Key Statistics.* [online] available from <http://www.coventry.gov.uk/info/200088/information_and_statistics/749/key_statistics> [23/09/2013]

Craig, C.L., Marshall, A.L., Sjostrom, M., Bauman, A.E. and Booth, M.L. (2003) 'International Physical Activity Questionnaire: 12 Country Reliability and Validity'. *Medicine and Science in Sports and Exercise* 35, 1381-195

Craig, R., Mindell, J., and Hirani, V. (2008) 'Physical Activity and Fitness, Health Survey for England.' *Department of Epidemiology and Public Health and National Centre for Social Research.*

Crewther, B. T., Kilduff, L. P., Cunningham D. J., Cook, C., Owen, N., Yang, G.-Z. (2011) 'Validating Two Systems for Estimating Force and Power'. *International Journal of Sports Medicine* 32, 254-258

Crouter, S. E., P. L. Schneider, M. Karabulut, and D. R. Bassett. (2003) 'Validity of Ten Electronic Pedometers for Measuring Steps, Distance, and Energy Cost. 2003'. *Medicine and Science in Sports and Exercise* 35, 1455-1460

Crouter, S.E., Schneider, P.L. and Bassett, D.R. (2005) 'Spring Leverd Versus Piezo-Electric Pedometer Accuracy in Overweight and Obese Adults'. *Medicine and Science in Sports and Exercise* 37, 1673-1679

Current Results, Research and Science Facts; CRRSF (2014) Average Annual Precipitation for the United Kingdom. [online] available from <http://www.currentresults.com/Weather/United-Kingdom/average-yearly-precipitation.php> [13/11/14]

De Bourdeaudhuij, I., Sallis, J.F. and Saelens, B.E. (2003) 'Environmental Correlates of Physical Activity in a Sample of Belgian Adults.' *American Journal of Health Promotion* 18, 82-92

Department for culture, media and sport (DCMS) Taking Part 2011/12 Adult and Child Report. . [online] available from <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/231004/Taking_Part_Year_8_2012_13_Child_Report.pdf> [14/01/15]

Department for Environment (2012) Annual average rainfall and temperature [online] available from <https://www.gov.uk/government/statistics/annual-average-rainfall-and-temperature> [13/11/14]

Department of Health (2013) *Reducing Obesity and Improving Diet* [online] available from <https://www.gov.uk/government/policies/reducing-obesity-and-improving-diet> [27/06/2013]

Department of Health (2013) *Reducing Obesity and Improving Diet* [online] available from <https://www.gov.uk/government/policies/reducing-obesity-and-improving-diet> [03/04/2014]

Department of Health (2011) *Physical Activity Guidelines for Children and Young People (2-18years)* [online] available from <https://www.gov.uk/government/publications/uk-physical-activity-guidelines> [27/06/2013]

Derri, V. and Patcha, M. (2007) 'Motor Skills and Concepts Acquisition and Retention: A Comparison between Two Styles of Teaching.'. *International Journal of Sport Science* 9, 37-47

Derri, V., Tsapakidou, A., Zachopoulou, E. and Kioumourtzoglou, E. (2001) 'Effect of a Music and Movement Programme on Development of Locomotor Skills by Children 4-6 Years of Age'. *European Journal of Physical Education* 6, 16-25

D'Hondt, E., Deforche, B., De Bourdeaudhuij, I., and Lenoir, M. (2009) 'Relationship between Motor Skill and Body Mass Index in 5- to 10-Year-Old Children'. *Adapted Physical Activity Quarterly* 26, 21-37

Dishman, R. K., Heath, G. W., and Lee, I. M. (2013) *Physical Activity Epidemiology.* Second edn. Champaign: IL, USA: Edwards Brothers Malloy

Dishman, R. K., Washburn, R. A., and Schoeller, D. A. (2001) 'Measurement of Physical Activity'. *Quest* 53, 295-309

Donnelly, J.E., Blair, S.N., Jakicic, J.M., Manore, M.M., Rankin, J.W. and Smith, B.K. (2009) 'Appropriate Physical Activity Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults'. *American College of Sports Medicine* 41, 459-471

Duncan, G. J., Ludwig, J., and Magnuson, K. A. (2007) 'Reducing Poverty through Preschool Interventions.' *Future Child* 17, 143-160

Duncan, T.E. and Duncan, S.C. (1991) 'A Latent Growth Curve Approach to Investigating development6al Dynamics and Correlates of Change in children's Perceptions of Physical Competence.' *Research Quarterly for Exercise and Sport* 62, 390-398

Duncan, M. J., Al-Nakeeb, Y., and Nevill, A. M. (2009) 'Effects of a 6-Week Circuit Training Intervention on Body Esteem and Body Mass Index in British Primary School Children'. *Body Image* 6, 216-220

Duncan, M. J., Al-Nakeeb, Y., Woodfield, L., Lyons, M. (2007) 'Pedometer determined physical activity levels in primary school children from central England'. *Preventative Medicine* 44, 416-420

Ebben, W. P., Petushek, E. J., and Clewein, R. (2009) 'A Comparison of Manual and Electronic Timing during 20 and 40 Yards Sprints'. *Journal of Exercise Physiology* 12, 34-39

Edlin, G., Golanty, E., and Brown, K. (2000) *Essentials for Health and Wellness.* Second edn. London, UK: Jones and Bartlett

Edwards, W. H. (2011) *Motor Learning and Control: From Theory to Practice.* Wadsworth, Cengage Learning. Belmont, USA.

Eime, R., Payne, W., and Harvey, J. (2009) 'Trends in Organised Sport Membership: Impact on Sustainability'. *Journal of Science and Medicine in Sport* 12, 123-129

Ekeland, E., Heian, F., Hagan, K.B., Abbott, J.M. and Nordheim, L. (2004) 'Exercise to Improve Self-Esteem in Children and Young People.'. *Cochrane Database of Systematic Reviews* 1, 1-37

Elgethun, K., Yost, M. G., Fitzpatrick, C.T.E., Nyerges, T.L. and Fenske, R.A. (2006) 'Comparison of Global Positioning System (GPS) Tracking and Parent-Report Diaries to Characterize Children's Time-Location Patterns'. *Journal of Exposure Science and Environmental Epidemiology* 17, 196-206

Elowsson, P., Forslund, A.H., Mallmin, H., Feuk, U., Hansson, I. and Carlsten, J. (1998) 'An Evaluation of Dual X-Ray Absorptiometry and Underwater Weighing to Estimate Body Composition by Means of Carcass Analysis in Piglets'. *Journal of Nutrition* 128, 1543-1549

Enoka, R. M. (2002) *Neuromechanics of Human Movement.* third edn. Champaign: IL, USA: Human Kinetics

Epstein, L. H., Wing, R. R., Valoski, A., and Gooding, W. (1987) 'Long-Term Effects of Parent Weight on Child Weight Loss'. *Behaviour Therapy* 18, 219-226

Erguson K.J., Yesalis, C.E., Pomrehn, P.R. and Kirkpatrick, M.B. (1989) 'Attitudes, knowledge, and beliefs as predictors of exercise intent and behaviour in schoolchildren'. *Journal of School Health* 59, 112-115.

Eriksen, L., Curtis, T., Grønbæk, M., Helge, J. W., and Tolstrup, J. S. (2013) 'The Association between Physical Activity, Cardiorespiratory Fitness and Self-Rated Health'. *Preventive Medicine* 57, 900-902

Erwin, H. E. and Castelli, D. M. (2008) 'National Physical Education Standards: A Summary of Student Performance and its Correlates'. *Research Quarterly for Exercise and Sport* 79, 495-505

Eston, R. G., Rowlands, A. V., and Ingledew, D. K. (1998) 'Validity of Heart Rate, Pedometry, and Accelerometry for Predicting the Energy Cost of Childrens Acitivites'. *Journal of Applied Physiology* 84, 362-371

Faigenbaum, A.D., Kraemer, W.J., Blimkie, C.J., Jeffreys, I., Micheli, L.J., Nitka, M., Rowland, T.W. (2009) 'Youth resistance training: updated position statement paper from the national strength and conditioning association'. *Journal of Strength and Conditioning Research* 23, 60-79

Fairbrother, J. T. (2010) *Fundamentals of Motor Behaviour.* Leeds, UK: Human Kinetics

Fairclough, S. J. and Stratton, G. (2005) 'Physical Activity Levels in Middle and High School Physical Education: A Review'. *Pediatric Exercise Science* 17, 217-236

Fairclough, S. J. and Stratton, G. (2005) ''Physical Education Makes You Fit and Healthy' Physical Education's Contribution to Young People's Physical Activity Levels'. *Health Education Research* 20, 14-23

Fairclough, S. J. (2003) 'Physical Activity Levels during Key Stage 3 Physical Education 34'. *British Journal of Teaching Physical Education* 34, 40-45

Fairclough, S. J., Hackett, A. F., Davies, I. G., Gobbi, R., Mackintosh, K. A., Warburton, G. L., Stratton, G., van Sluijs, Esther M. F., and Boddy, L. M. (2013) 'Promoting Healthy Weight in Primary School Children through Physical Activity and Nutrition Education: A Pragmatic Evaluation of the CHANGE! Randomised Intervention Study'. *BMC Public Health* 13, 1-14

Fawcett, L. M. and Garton, A. F. (2005) 'The effect of peer collaboration on children's problem-solving ability'. *British Journal of Educational Psychology* 75, 157-169

Feltz, D. and Brown, E. (1984) 'Perceived Competence in Soccer Skills among Young Soccer Players'. *Journal of Sport Psychology* 6, 385-394

Fiatarone, M.A., O'Neill, E.F., Ryan, N.D., Clements, K.M., Solares, G. R., Nelson, M.E., Roberts, S.B.,Kehayias, J.J., Lipsitz, L.A., Evans, W.J. (1994) 'Exercise training and nutritional supplementation for physical frailty in very elderly people'. *New England Journal of Medicine* 330, 1769 - 1775

Fink, H., Burgoon, L. and Mikesky, A. (2009) *Practical Applications in Sports Nutrition*. second edn. Champaign: IL, USA: Jones and Bartlett Publishers

Fisher, A., Reilly, J. J., Kelly, L. A., Montgomery, C., Williamson, A., Paton, J. Y., and Grant, S. (2005) 'Fundamental Movement Skills and Habitual Physical Activity in Young Children'. *Medicine and Science in Sports and Exercise* 37, 684-688

Fitts, P.M. and Posner, M. I. (1967) *Human Performance*. Belmont: CA, USA: Brooks/Cole

Fogelholm, M. and Kukkonen-Harjula, K. (2000) 'Does Physical Activity Prevent Weight Gain ? a Systematic Review'. *Obesity Reviews* 1, 95-111

Foley, L., Prapavessis, H., Maddison, R., Burke, S., McGowan, E. and Gillanders, L. (2008) 'Predicting Physical Activity Intention and Behaviour in School-Age Children'. *Paediatric Exercise Science* 20, 342-356

Folio, M. R. and Fewell, R. R. (1983) *Peabody Development Motor Scales and Activity Cards*. Austin: TX, USA: PRO-ED

Foresight (2008) *Tackling Obesities: Future Choices*. London, UK: Government Office for Science

Foresight (2007) *Tackling Obesities: Future choices—project Report. London: The Stationery Office, 2007.* London, UK: The Stationary Office

Foweather, L., McWanneell, N., Henaghan, J., Lees, A. and Stratton, G. (2008) 'Effect of a 9 Week After School Multoskills Club on Fundamental Movement Skill Proficiency in 8-9 Year Old Children: An Exploratory Trial'*. Perceptual and Motor Skills* 106, 745-754

Fox, C. K., Barr-Anderson, D., Neumark-Sztainer, D., and Wall, M. (2010) 'Physical Activity and Sports Team Participation: Associations with Academic Outcomes in Middle School and High School Students'*. Journal of School Health* 80, 31-37

Freedman, D. S., Horlick, M. and Berenson, G. S. (2013) 'A comparison of the Slaughter skinfold-thickness equations and BMI in predicting body fatness and cardiovascular disease risk factor levels in children'*. American Journal of Clinical Nutrition* 98, 1417 – 1424

Freedson, P., Pober, D., and Janz, K. F. (2005) 'Calibration of Accelerometer Output for Children'*. Medicine and Science in Sports and Exercise* 37, 523-530

Frontear, W. (2007) *Clinical Sports Medicine: Medical Management and Rehabilitation,* London, UK: Elsevier Saunders Publishing

Gagan, L. and Getchell, N. (2006) 'Using 'Constraint' to Design Development Appropriate Movement Activity for Early Childhood Education'*. Early Childhood Education Journal* 34, 227-232

Gallahue, D., Ozmun, J.C. (2006) *Understanding Motor Development: Infants, Children, Adolescents, Adults.* Sixth edn. Boston, USA: McGraw-Hill

Galli, M., Cimolin, V., Patti, P., Ferrario, D., Heaney, G., Albertini, G., Freedland, R. (2010) 'Quantifying established clinical assessment measures using 3D-movement analysis in individuals with Down syndrome'*. Disability Rehabilitation* 32, 1768-1774

Garasky, S., Stewart, S. D., Gundersen, C., Lohman, B. J., and Eisenmann, J. C. (2009) 'Family Stressors and Child Obesity'*. Social Science Research* 38, 755-766

Garcia, A.W., Broda, M.A.N., Frenn, M., Coviak, C., Pender, N.J. and Ronis, D.L. (1995) 'Gender and developmental differences in exercise beliefs among youth and prediction of their exercise behaviour'*. Journal of School Health* 65, 213-219.

Gauvain, M. and Rogoff, B. (1989) 'Collaborative problem solving and children's planning skills'*. Developmental Psychology.* 25, 139-151

Gazzola, V., Rizzolatti, G., Wicker, B., and Keysers, C. (2007) 'The Anthropomorphic Brain: The Mirror Neuron System Responds to Human and Robotic Actions'. *Neuroimage* 35, 1674-1684

Gentile, A. M. (1972) 'A Working Model of Skill Acquisition with Application to Teaching'. *Quest* 17, 3-23

George, S. J. and Johnson, J. (2010) *Atherosclerosis.* Boschstrasse, Germany: Wiley - VCH

Giles-Corti, B. and Donovan, R. J. (2002) 'Socioeconomic Status Differences in Recreational Physical Activity Levels and Real and Perceived Access to a Supportive Physical Environment'. *Preventive Medicine.* 35, 601-611

Giuliodori, M. J. and DiCarlo, S. E. (2004) 'Myelinated Vs. Unmyelinated Nerve Conduction: A Novel Way of Understanding the Mechanisms'. *Advances in Physiology Education* 28, 80-81

Go´mez-Pinilla, F., Ying, Z., Roy, R.R., Molteni, R., Edgerton, V.R. (2002) 'Voluntary exercise induces a BDNF-mediated mechanism that promotes neuroplasticity'. *Journal of Neurophysiology* 88, 2187–95

Goodway, J. D. and Branta, C. F. (2003) 'Influence of a Motor Skill Intervention on Fundamental Motor Skill Development of Disadvantaged Preschool Children'. *Research Quarterly for Exercise and Sport* 74, 36-46

Goodway, J. D. and Rudisill, M. E. (1997) 'Perceived Physical Competence and Actual Motor Competence of African American Preschool Children'. *Adapted Physical Activity Quarterly* 14, 314-326

Gortmaker, S. L., Cheung, L. W. Y., Peterson, K. E., Chomitz, G., Cradle, J. H., Dart, H., Fox, M. K., Bullock, R. B., Sobol, A. M., Colditz, G., Field, A. E., and Laird, N. (1999) 'Impact of a School-Based Interdisciplinary Intervention on Diet and Physical Activity among Urban Primary School Children: Eat Well and Keep Moving'. *Archives of Pediatrics and Adolescent Medicine* 153, 975-983

Graf, C., Koch, B., Falkowski, G., Jouck, S., Christ, H., Staudenmaier, K., Tokarski, W., Gerber, A., Predel, H. and Dordel, S. (2008) 'School-Based Prevention: Effects on Obesity and Physical Performance After 4 Years'. *Journal of Sports Sciences* 26, 987-994

Graf, C., Koch, B., Kretschmann-Kandel, E., Falkowski, G., Christ, H., Coburger, S., Lehmacher, W., Bjarnason-Wehrens, B., Platen, P., Tokarski, W., Predel, H. G., and Dordel, S. (2004) 'Correlation between BMI, Leisure Habits and Motor Abilities in Childhood (CHILT-Project)'. *International Journal of Obesity* 28, 22-26

Green, K. (2008) *Understanding Physical Education*. First edn. London, UK: SAGE

Griffiths, L. J., Wolke, D., Page, A. D., and Horwood, J. P. (2005) ' Obesity and Bullying: Different Effects for Boys and Girls. '*. The British Medical Journal* 91, 121-125

Gumbiner, B. (2001) *Obesity*. Philadelphia, USA: Versa Press American College of Physicians

Gutin, B., Islam, S., Manos, T., Cucuzzo, N., Smith, C., and Stachura, M. E. (1994) 'Relation of Percentage of Body Fat and Maximal Aerobic Capacity to Risk Factors for Atherosclerosis and Diabetes in Black and White Seven- to Eleven-Year-Old Children'*. The Journal of Pediatrics* 125, 847-852

Haga, M. (2008) 'The Relationship between Physical Fitness and Motor Competence in Children.' *Child: Care, Health and Development* 34, 329-334

Hammond, J. (1995) 'Investigation into the Characteristics of Children with Motor Difficulties: A Holistic Approach'*. Armidale, NSW: University of New England*

Hamstra-Wright, K. L., Swanik, C. B., Sitler, M. R., Swanik, K. A., Ferber, R., Ridenour, M., and Huxel, K. C. (2006) 'Gender Comparisons of Dynamic Restraint and Motor Skill in Children'*. Clinical Journal of Sport Medicine* 16, 56-62

Hands, B. (2008) 'Changes in Motor Skill and Fitness Measures among Children with High and Low Motor Competence: A Five-Year Longitudinal Study'*. Journal of Science and Medicine in Sport* 11, 155-162

Hardy, L. L., King, L., Espinel, P., Okely, A. D., and Bauman, A. (2011) 'Methods of the NSW Schools Physical Activity and Nutrition Survey 2010 (SPANS 2010)'*. Journal of Science and Medicine in Sport* 14, 390-396

Harten, N., Olds, T., and Dollman, J. (2008) 'The Effects of Gender, Motor Skills and Play Area on the Free Play Activities of 8–11 Year Old School Children'*. Health and Place* 14, 386-393

Harter, S. (1982) 'The Perceived Competence Scale for Children'*. Child Development* 53, 87-97

Hawk, L. (2012) H*ow Does the ActiGraph Device Determine Inclination (for Waist Wear Locations)?* [online] available from <https://help.theactigraph.com/entries/22652363-How-Does-The-

ActiGraph-Device-Determine-Inclination-for-Waist-Wear-Locations>
[03/07/2014]

Haywood, K. M., and Getchell, N. (2009) *Life Span Motor Development*. Fifth edn. Champaign: IL: Human Kinetics Publishers

Haywood, K.M., Roberton, M.A. and Getchall, N. (2012) *Advanced Analysis of Motor Development*. Leeds, UK: Human Kinetics

Health and Social Care Information Centre, Lifestyles Statistics (2013) *Statistics on Obesity, Physical Activity and Diet: England, 2013*. [online] available from <http://www.hscic.gov.uk/catalogue/PUB10364/obes-phys-acti-diet-eng-2013-rep.pdf> [01/08/2014]

Helwig, C. C., Ryerson, R., and Prencipe, A. (2008) 'Children's, Adolescents', and Adults' Judgments and Reasoning about Different Methods of Teaching Values'. *Cognitive Development* 23, 119-135

Henderson, S.E. and Sugden, D.A. (1992) *Movement Assessment Battery for Children*. London, UK: The Psychological Corporation

Hetzler, R. K., Stickley, C. D., Lundquist, K. M. and Kimura, I.F (2008) 'Reliability and Accuracy of Handheld Stopwatches Compared with Electronic Timing in Measuring Sprint Performance.' *Journal of Strength and Conditioning Research* 22, 1969-1976

Heyward, V. and Wagner, D. (2004) *Applied Body Composition Assessment*. Second edn. Leeds, UK: Human Kinetics

Hjorth, M. F., Chaput, J. P., Ritz, C., Dalskov, S. M., Andersen, R., Astrup, A., Tetens, I., Michaelsen, K. F. and Sjodin, A. (2014) 'Fatness predicts decreased physical activity and increased sedentary time, but not vice versa: support from a longitudinal study in 8- to 11-year-old children'. *International Journal of Obesity* 38, 959-965

Hodges-Kulinna, P., Martin, J., Lai, Q., Kliber, A. and Reed, B. (2003) 'Student Physical Activity Patterns: Grade, Gender and Activity Influences'. *Journal of Teaching in Physical Education* 22, 298-310

Hoffer, E.C., Meador, C.K. and Simpson, D.C., (1969) 'Correlation of whole-body impedance with total body water'. *Journal of Applied Physiology* 27, 53l-4.

Hoffman,D. J., Toro-Ramos, T., Sawaya, A. L., Roberts, S. B. and Rondo, P. (2012) 'Estimating Total Body Fat using a Skinfold Prediction Equation in Brazilian Children'. *Annals of Human Biology* 39, 156-160

Holbrook, M.C., Koenig, A. J. (2000) *Foundations of Education*. second edn. New York, USA: AFB Press

Horn, T. and Hasbrook, C. (1987) ' Psychological Characteristics and the Criteria Children use for Self-Evaluation.' *Journal of Sport Psychology* 9, 208-221

Howie, E. K. and Pate, R. R. (2012) 'Physical Activity and Academic Achievement in Children: A Historical Perspective'. *Journal of Sport and Health Science* 1, 160-169

Human Kinetics (2008) *Coaching Youth Track and Field*. First edn. Champaign: IL, USA: United Graphics

Hume, C., Okely, A., Bagley, S., Telford, A., Booth, M., Crawford, D., and Salmon, J. (2008) 'Does Weight Status Influence Associations between Children's Fundamental Movement Skills and Physical Activity?' *Research Quarterly for Exercise and Sport* 79, 158-165

Ignico, A. (1990) 'The Influence of Gender Role Perception on Activity Preferences of Children'. *Play Culture* 3, 302-310

Ives, J. C. (2014) M*otor Behaviour Connecting Mind and Body for Optimal Performance.* Lippincott Williams and Wilkins. China.

Jabs, J. and Devine, C. M. (2006) 'Time Scarcity and Food Choices: An Overview'. *Appetite* 47, 196-204

Jackson, A. S., Pollock, M. L, Graves, J. E., Mahar, M. T. (1988) 'Reliability and validity of bioelectrical impedance in determining body composition'. *Journal of Applied Physiology* 64, 529-534

Jette, M., Sidney, K., and Blumchen, G. (1990) 'Metabolic Equivalents (METS) in Exercise Testing, Exercise Prescription, and Evaluation of Functional Capacity.' *Clinical Cardiology* 13, 555-565

Jidovtseff. B., Crielaard, J. M., Cauchy, S., Croisier, J.L . (2008) 'Validity and reliability of an inertial dynamometer using accelerometry'. *Science and Sport* 23, 94–97.

Jones, R. A., Okely, A. D., Caputi, P., and Cliff, D. P. (2010) 'Perceived and Actual Competence among Overweight and Non-Overweight Children'. *Journal of Science and Medicine in Sport* 13, 589-596

Jones, R. A. and Riethmuller, A. (2011) 'Promoting Fundamental Movement Skill Development and Physical Activity in Early Childhood Settings: A Cluster Randomized Controlled Trial'. *Pediatric Exercise Science,* 23, 600-615

Kahl, H. and Emmel, J. (2002) 'The Examination of Motor Activity in the Pilot Study of the National Health Interview and Examination Survey for Children and Adolescents'. *Gesundheitswesen* 64, S114-S118

Kantomaa, M. T., Tammelin, T. H., Demakakos, P., Ebeling, H. E., and Taanila, A. M. (2010) 'Physical Activity, Emotional and Behavioural Problems, Maternal Education and Self-Reported Educational Performance of Adolescents'. *Health Education Research* 25, 368-379

Kelder, S., Perry, C., and Klepp, K. and Lytle L., (1994) 'Longitudinal Tracking of Adolescents Smoking, Physical Activity and Food Choices Behaviour.' *American Journal of Public Health* 84, 1121-1126

Kellis, E. and Katis, A. (2007) 'Biomechanical Characteristics and Determinants of Instep Soccer Kick'. *Journal of Sports Science and Medicine* 6, 154-165

Kelly, L. A., Reilly, J. J., Fisher, A., Montgomery, C., Williamson, A., McColl, J. H., Paton, J. Y., and Grant, S. (2006) 'Effect of Socioeconomic Status on Objectively Measured Physical Activity'. *Archives of Disease in Childhood* 91, 35-38

Kelso, J. A. (1982) *Human Motor Behaviour.* Hillsdale, New Jersey: Lawrence Erlbaum Associates

Kimiecik, J., Horn, T., and Shurin, C. (1996) ' Relationship among Children's Beliefs, Perceptions of their Parent's Beliefs, and their Moderate to Vigorous Physical Activity'. *Research Quarterly for Exercise and Sport* 67, 324-336

Kirtley, C. (2006) *Clinical Gait Analysis; Theory and Practice.* Philadelphia, USA: Elsevier

Kjonniksen, L., Torsheim, T. and Wold, B. (2008) 'Tracking of Leisure-Time Physical Activity during Adolescence and Young Adulthood: A 10-Year Longitudinal Study'. *International Journal of Behavioural Nutrition and Physical Activity* 5, 1-11

Kline, R. B. (2005) *Principles and Practice of Structural Equation Modelling.* New York, USA: The Guilford Press.

Kopp, H.P., Kopp, C. W., Festa, A., Krzyzanowska, K., Krwanek, S., Minar, E., Roka, R. and Schernthaner, G. (2003) 'Impact of Weight Loss on Inflammatory Proteins and their Association with the Insulin Resistance Syndrome in Morbidly Obese Patients.' *Journal of the American Heart Association* 23, 1042-1047

Krishnaveni, G. V., Veena, S. R., Kuriyan, R., Kishore, R. P., Wills, A. K., Nalinakshi, M., Kehoe, S., Fall, C. H. D., and Kurpad, A. V. (2009) 'Relationship between Physical Activity Measured using Accelerometers and Energy Expenditure Measured using Doubly Labelled Water in Indian Children'. *European Journal of Clinical Nutrition* 63, 1313-1319

Labarthe, D. R. (2011) *Epidemiology and Prevention of Cardiovascular Diseases: A Global Challenge*. Second edn. Champaign: IL, USA: Jones and Barlett Publishers

Lahti-Koskia, M. G. T. (2004) 'Defining Obesity'. *Obesity in Childhood and Adolescence.* 9, 1-19

Lakdawalla, D. and Philipson, T. (2009) 'The Growth of Obesity and Technological Change'. *Economics and Human Biology* 7, 283-293

Lamari, N.M., Chueire, A. G. and Cordeiro, J. A. (2005) 'Analysis of joint mobility patterns among preschool children'. *Sao Paulo Medical Journal* 123, 119-123

Langer, S. L., Crain, A.L., Senso, M. M., Levy, R. L. and Sherwood, N. E. (2014) 'Predicting child physical activity and screen time: parental support for physical activity and general parenting styles'. *Journal of Paediatrics Psychology* 39, 633-642

LeBoeuf, R. (2013) 'Barriers to Physical Activity in Children'. *Journal of Pediatric Nursing* 29, 100-101

Lee, P. H., Macfarlane, D. J., Lam, T. H., and Stewart, S. M. (2011) 'Validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF): A Systematic Review'. *International Journal of Behavioural Nutrition and Physical Activity* 8, 115-126

Leenders, N., Ramirez-Marrero, F. A., and Smith, B. A. (1997) 'Evaluation of a Step Count in African American Children'. *Medicine and Science in Sports and Exercise* 29, 70

Lenroot, R. K and Giedd, J. N. (2006) 'Brain Development in Children and Adolescents: Insights from Anatomical Magnetic Resonance Imaging'. *Neuroscience and Biobehavioral Reviews* 30, 718-729

Leong, K. S. and Wilding, J. P. (1999) 'Obesity and Diabetes'. *Best Practice and Research Clinical Endocrinology and Metabolism* 13, 221-237

Li, J. and Siegrist, J. (2012) 'Physical Activity and Risk of Cardiovascular Disease—A Meta-Analysis of Prospective Cohort Studies'. *International Journal of Environmental Research and Public Health* 9, 391-407

Lopes, V. P., Stodden, D. F, Bianchi, M. M., Maia, J. A. R. and Rodrigues, L. P. (2011) 'Correlation between BMI and Motor Coordination in Children'. *Journal of Science and Medicine in Sport* 626, 1-6

Loucaides, C. A., Chedzoy, S. M. and Bennett, N. (2004) 'Differences in physical activity levels between urban and rural school children in Cyprus'. *Health Education Research* 19, 138-147

Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., and Okely, A. D. (2010) 'Fundamental Movement Skills in Children and Adolescents: Review of Associated Health Benefits'. *Sports Medicine* 40, 1019-1035

Lukaski, H.C., Johnson,P. E., Bolonchuk, W. W. Lykken, G. I. (1985) 'Assessment of fat-free mass using bioelectrical impedance measurements of the human body'. *The American Journal of Clinical Nutrition* 41, 810-817.

Maffeis, C. and Castellani, M. (2007) 'Physical Activity: An Effective Way to Control Weight in Children?' *Nutrition, Metabolism and Cardiovascular Diseases* 17, 394-408

Magill, R. A. (2001) *Motor Learning and Control: Concepts and Applications.* Seventh edn. New York, USA: McGraw Hill

Malina, R. M., Bouchard, C., and Bar-Or, O. (2004) *Growth, Maturation and Physical Activity.* Second edn: Champaign: IL, USA: Human Kinetics

Malina, R. M. (2001) 'Physical Activity and Fitness: Pathways from Childhood to Adulthood'. *American Journal of Human Biology* 13, 162-172

Markovic, G., Dizdar, D., Jukic, I. and Cardinale, M. (2004) 'Reliability and Factorial Validity of Squat and Countermovement Jump Tests'. *Journal of Strength and Conditioning Research* 18, 551-555

Martin, D. (1988) *Training in Kinders Und Jugendalter.* Verlag, Germany: K Hoffamann

Masuda, A., Hayes, S. C., Fletcher, L. B., Seignourel, P. J., Bunting, K., Herbst, S. A., Twohig, M. P., and Lillis, J. (2007) 'Impact of Acceptance and Commitment Therapy Versus Education on Stigma Toward People with Psychological Disorders'. *Behaviour Research and Therapy* 45, 2764-2772

McArdle, W. D., Katch, F. I., and Katch, V. L. (2010) *Exercise Physiology: Nutrition, Energy, and Human Performance.* Second edn. Philadelphia, USA: Lippincott Williams and Wilkins

McCullagh, P. and Meyer, K.N. (1997) 'Learning Versus Correct Models: Influence of Model Type on the Learning of a Free Weight Squat Lift'. *Research Quarterly for Exercise and Sport* 68, 56-61

McGraw, M. (1975) *Growth: A Study of Johnny and Jimmy.* New York, USA: Appleton-Century/Arno Press

McKenzie, T. L., Sallis, J. F., Broyles, S. L., Zive, M. M., Nader, P. R., Berry, C. C., and Brennan, J. J. (2002) 'Childhood Movement Skills: Predictors of Physical Activity in Anglo American and Mexican American Adolescents?'. *Research Quarterly for Exercise and Sport* 73, 238-244

McMorris, T. (2004) *Acquisition and Performance of Sports Skills*. West Sussex, England: John Wiley and Sons Ltd

McNamee, G. D. (2005) 'The One Who Gathers Children: The Work of Vivian Gussin Paley and Current Debates about how we Educate Young Children.' *Journal of Early Childhood Teacher Education* 25, 275-296

Mei, Z., Grummer-Strawn, L. M., Pietrobelli, A., Goulding, A., Goran, M. I., and Dietz, W. H. (2002) 'Validity of Body Mass Index Compared with Other Body-Composition Screening Indexes for the Assessment of Body Fatness in Children and Adolescents'. *American Journal of Clinical Nutrition* 75, 978-985

Mitchell, B., McLennan, S., Latimer, K., Graham, D., Gilmore, J., and Rush, E. (2013) 'Improvement of Fundamental Movement Skills through Support and Mentorship of Class Room Teachers'. *Obesity Research and Clinical Practice* 7, 230-234

Molteni, R., Ying, Z., Gomez-Pinilla, F. (2002) 'Differential effects of acute and chronic exercise on plasticity-related genes in the rat hippocampus revealed by microarray'. *European Journal of Neuroscience* 16, 1107–16

Mond, J. M., Hay, P. J., Rodgers, B., and Owen, C. (2007) 'Recurrent Binge Eating with and without the "undue Influence of Weight Or Shape on Self-Evaluation": Implications for the Diagnosis of Binge Eating Disorder'. *Behaviour Research and Therapy* 45, 929-938

Mota, J., Santos, P., Guerra, S., Ribeiro, J. C., and Duarte, J. A. (2003) 'Patterns of Daily Physical Activity during School Days in Children and Adolescents'. *American Journal of Human Biology* 15, 547-553

Murphy, E., Ice, C., McCartney, K., Leary, J., and Cottrell, L. (2012) 'Is Parent and Child Weight Status Associated with Decision Making regarding Nutrition and Physical Activity Opportunities?' *Appetite* 59, 563-569

Murray, L. (2006) *Sport, Exercise and Physical Activity: Public Participation, Barriers and Attitudes*. Edinburgh, Scotland: Information and Analytical Services Division

Must, A. and Strauss, R. S. (1999) 'Risks and Consequences of Childhood and Adolescent Obesity'. *International Journal of Obesity and Related Metabolic Disorders* 23, 1-12

National Institute for Health and Clinical Excellence (2009) *Promoting Physical Activity for Children and Young People.* London, UK: NICE

National Institute of Health (NIH) (2011) *What is Physical Activity* [online] available from <http://www.nhlbi.nih.gov/health/health-topics/topics/phys/> [27/06/2013]

Neeper, S.A., Gomez-Pinilla, F., Choi, J., Cotman, C.W. (1995) 'Exercise and brain neurotrophins'. *Nature* 373, 109

Nevill, A. M., Stewart, A. D., Olds, T., and Holder, R. (2006) 'Relationship between Adiposity and Body Size Reveals Limitations of BMI'. *American Journal of Physical Anthropology* 129, 151-156

New South Wales Department of Health (2003) *'Move it, Groove it - Physical Activity in Primary Schools' Summary Report*: New South Wales, Australia

Newell, K. M. (1991) 'Motor Skill Acquisition' *Annual Review of Psychology* 42, 213-37

Newton, R. U., Kraemer, W.J., Hakkinen, K., Humphries, B.J., and Murphy, A.J. (1996) 'Kinematics, kinetics, and muscle activation during explosive upper body movements: Implications for power development'. *Journal of Applied Biomechanics* 12, 31–43.

Norton, K. and Olds, T. (1996) *A Text Book of Body Measurements for Sports and Health Courses.* New South Wales, Australia: University of New South Wales Press Ltd

Nuzzo, J.L., Anning, J. H. and Scharfenberg, J.M. (2011) 'The reliability of three devices used for measuring vertical jump height'. *Journal of Strength and Conditioning Research* 25, 2580–2590

Office for national statistics (2011) Census data [online] available from <http://www.ons.gov.uk/ons/guide-method/census/2011/census-data/index.html> [13/11/14]

Ofsted (2013) *Press Release: Not enough Physical in Physical Education.* UK: Ofsted

Okely, A.D., Booth, M.L. (2000) 'The development and validation of an instrument to assess children's fundamental movement skills ability'. In: *Pre-Olympics Congress Abstracts,* 245.

Okely, A. D., Booth, M. L., and Chey, T. (2004) 'Relationships between Body Composition and Fundamental Movement Skills among Children and Adolescents'. *Research Quarterly for Exercise and Sport* 75, 238-247

Okely, A. D., Booth, M. L., and Patterson, J. W. (2001) 'Relationship of Physical Activity to Fundamental Movement Skills among Adolescents'. *Medicine and Science in Sports and Exercise* 33, 1899-1904

Oyeyemi, A. L., Umar, M., Oguche, F., Aliyu, S. U., and Oyeyemi, A. Y. (2014) *Accelerometer-Determined Physical Activity and its Comparison with the International Physical Activity Questionnaire in a Sample of Nigerian Adults*: Public Library of Science 9, 1-9

Page, A., Cooper, A. R., Stamatakis, L. J., Foster, L. J., Crowne, E. C., Sabin, M. and Shield, J. P. H. (2005) 'Physical activity patterns in nonobese and obese children assessed using minute-by-minute accelerometry'. *International Journal of Obesity* 29, 1070–1076

Parker, L., Reilly, J. J., Slater, C., Wells, J. C. K., and Pitsiladis, Y. (2003) 'Validity of Six Field and Laboratory Methods for Measurement of Body Composition in Boys'. *Obesity Research* 11, 852-858

Paxton, R.J., Estabrooks, P.A. and Dzewaltowski, D. A. (2004) 'Attraction to physical activity mediates the relationship between perceived competence and physical activity in youth'. *Research Quarterly for Exercise and Sport* 75. 107 – 111

Payton, C.J., Bartlett, R.M (2008) *Biomechanical Evaluation of Movement in Sport and Exercise.* London, UK: Routledge

Peacock, J. (2000) *Diabetes.* Minnesota, USA: Capstone Press

Perez-Gomez, J. R., Olmedillas, H. C. J., González-Henriquez, J.J., Dorado, C. and Calbet, J. A. L. (2008) 'Role of Muscle Mass on Sprint Performance: Gender Differences?' European Journal of Applied Physiology. 102, 685-694

Plasqui, G. and Westerterp, K. R. (2007) 'Physical Activity Assessment with Accelerometers: An Evaluation Against Doubly Labelled Water'. *Obesity* 15, 2371-2379

Poulin-Dubois, D., Serbin, L. A., Eichstedt, J. A., Sen, M. G., and Beissel, C. F. (2002) 'Men Don't Put on make-Up: Toddlers? Knowledge of the Gender Stereotyping of Household Activities'. *Social Development* 11, 166-181

Poulsen, A. A., Desha, L., Ziviani, J., Griffiths, L., Heaslop, A., Khan, A., and Leong, G. M. (2011) 'Fundamental Movement Skills and Self-Concept of Children Who are Overweight'. *International Journal of Pediatric Obesity* 6, 464-471

Prentice, A. M. and Jebb, S. A. (2001) 'Beyond Body Mass Index'. *Obesity Reviews* 2, 141-147

Puyau, M. R., Adolph, A. L., Vohra, F. A., Zakeri, I., and Butte, N. F. (2004) 'Prediction of Activity Energy Expenditure using Accelerometers in Children'. *Medicine and Science in Sports and Exercise* 36, 1625-1631

Qualifications and Curriculum Authority (2007) *Physical Education: Programme of Study for Key Stage 3 and Attainment Target.* London, UK: QCA

Raudsepp, L., Liblik, R. and Hannus, A. (2002) 'Children's and adolescents' physical self-perceptions as related to moderate to vigorous physical activity and physical fitness'. *Paediatric Exercise Science* 14, 97-106

Rey-López, J. P., Vicente-Rodríguez, G., Biosca, M., and Moreno, L. A. (2008) 'Sedentary Behaviour and Obesity Development in Children and Adolescents'. *Nutrition, Metabolism and Cardiovascular Diseases* 18, 242-251

Reynolds, K.D., Killen, J.D. and Bryson, S.W. (1990) 'Psychosocial predictors of physical activity in adolescents'. *Preventative Medicine* 19, 541-551

Riddoch C.J. (1995) 'The Health-Related Physical Activity of Children.' *Sports Medicine* 19, 86-102

Riddoch, C. J., Andersen, L. B., Wedderkopp, N., Harro, M., Klasson-Heggebø, L., Sardinha, L. B., Cooper, A. R., and Ekelund, U. (2004) 'Physical Activity Levels and Patterns of 9- and 15-Yr-Old European Children'. *Medicine and Science in Sports and Exercise* 36, 86-92

Ridgers, N., Barnett, L., Hanna, L., and Salmon, J. (2012) 'Parents and Children's Perceptions of Whether Active Video Games can Help Children's Fundamental Movement Skills'. *Journal of Science and Medicine in Sport* 15, 1440-2440

Roberton, M. A. (1989) 'Motor Development: Recognizing our Roots, Charting our Future'. *Quest* 41, 213-223

Robinson, L. E. and Goodway, J. D. (2009) 'Instructional Climates in Preschool Children Who are at-Risk. Part I: Object-Control Skill Development'. *Research Quarterly for Exercise and Sport* 80, 533-542

Robinson, L. E. (2011) 'Effect of a Mastery Climate Motor Program on Object Control Skills and Perceived Physical Competence in Pre-schoolers'. *Research Quarterly for Exercise and Sport* 82, 355-9

Rodriguez, G., Moreno, L.A., Blay, M.G., Blay, V.A., Fleta, J., Sarrı´a, A. and Bueno, M. (2005) 'Body Fat Measurement in Adolescents: Comparison of Skinfold Thickness Equations with Dual-Energy X-Ray Absorptiometry.' *European Journal of Clinical Nutrition* 59, 1158-1166

Rothney, M. P., Brychta, R. J., Schaefer, E. V., Chen, K. Y., and Skarulis, M. C. (2009) 'Body Composition Measured by Dual-Energy X-Ray Absorptiometry Half-Body Scans in Obese Adults'. *Obesity* 17, 1281-1286

Rowe, D.A., Mahar, M.T., Raedeke, T.D., and Lore, J. (2004) 'Measuring Physical Activity in Children with Pedometers: Reliability, Reactivity, and Replacement of Missing Data'. *Pediatric Exercise Science* 16, 1-12

Rowlands, A. V., Pilgrim, E. L., and Eston, R. G. (2008) 'Patterns of Habitual Activity Across Weekdays and Weekend Days in 9–11-Year-Old Children'. *Preventive Medicine* 46, 317-324

Saaty, T. L. (2013) *Fundamentals of Decision Making and Priority Theory.* Second edn. Pittsburgh, USA: RWS Publications

Sallis, J.F., Alcaraz, J.E., McKenzie, T.L. and Hovell, M.F. (1999) 'Predictors of change in children's physical activity over 20 months: variations by gender and level of adiposity'. *American Journal of Preventative Medicine* 16, 222-229

Sallis, J. F., Buono, M. J., Roby, J., Carlson, D., and Nelson, J. A. (1990) 'The Caltrac Accelerometer as a Physical Activity Monitor for School Aged Children.' *Medicine and Science in Sports and Exercise* 22, 698-703

Sallis, J., McKenzie, T., Alcaraz, J., Kolody, B., Faucette, N., and Hovell, M., (1997) 'The Effects of a 2-Year Physical Education (SPARK) Program on Physical Activity and Fitness of Elementary School Children.' *American Journal of Public Health* 87, 1328-1334

Sallis, J.F., Prochaska, J. J., Taylor, W. C. (2000) 'A review of correlates of physical activity of children and adolescents'. *Medicine and Science in Sports and Exercise* 32, 936-975

Sandercock, G. R. H., Taylor, M. J., Voss, C., Ogunleye, A. A., Cohen, D. D. and Parry, D A. (2013) 'Quantification of the Relative Age Effects in Three Indices of Physical Performance'. *Journal of Strength and Conditioning Research* 27, 3293-3299

Santos, P. M., Oliveira, J., Ribeiro, J. C. and Mota, J. (2009) 'Active travel to school, BMI and participation in organised and non-organised physical activity among Portuguese adolescents'. *Preventive Medicine* 49, 497–499

Sarchin, A., Por, H. B., and Sedighi, M. and Miri, S.A. (2012) 'Alteration of Dynamic Control Posture on Y-Balance Test After Different Fatigue Protocols'. *Annals of Biological Research* 3, 3350-3356

Sardinha, L. B., Going, S. B., Teixeira, P. J., and Lohman, T. G. (1999) 'Receiver Operating Characteristic Analysis of Body Mass Index, Triceps Skinfold Thickness, and Arm Girth for Obesity Screening in Children and Adolescents'. *American Journal of Clinical Nutrition* 70, 1090-1095

Sargent, D. A. (1921) 'The Physical Test of Man'. *American Physical Education Review* 26, 188-194

Schaben, J. A., Welk, G. J., Joens-Matre, R. and Hensley, L. (2006) 'The Predictive Utility of the Children's Physical Activity Correlates (CPAC)

Scale Across Multiple Grade Levels'. *Journal of Physical Activity and Health* 3, 59-69

Schmidt, R. A. (1975) 'A Schema Theory of Discrete Motor Skill Learning'. *Psychology Review* 82, 225-260

Schmidt, R. A. and Lee, T. D. (2011) *Motor Control and Learning*, 5<sup>th</sup> edition. Human Kinetics. Champaign, IL, USA

Schmidt, R.A. and Wrisberg, C.A (2008) *Motor Learning and Performance. A Situation-Based Learning Approach.* Leeds, UK: Human Kinetics

Siegel, J.A., Camaione, D.N., Manfredi, T.G. (1989) 'The effects of upper body resistance training on prepubescent children'. *Paediatric Exercise Science* 1, 145 - 154

Sigelman, C. and Rider, E. (2012) *Life-Span Human Development.* Belmount, USA: Wadsworth, Cengage Learning

Sigmund, E., El Ansari, W., and Sigmundová, D. (2012) 'Does School-Based Physical Activity Decrease Overweight and Obesity in Children Aged 6-9 Years? A Two-Year Non-Randomized Longitudinal Intervention Study in the Czech Republic'. *BMC Public Health* 12, 570-582

Sih, B.L., Hubbard, M. and Williams, K. R. (2001) 'Technical Note: Correcting Out-of-Plane Errors in Two-Dimensional Imaging using Nonimage-Related Information'. *Journal of Biomechanics* 34, 257-260

Singh, G. K., Kogan, M. D., Van Dyck, P. C., and Siahpush, M. (2008) 'Racial/Ethnic, Socioeconomic, and Behavioral Determinants of Childhood and Adolescent Obesity in the United States: Analysing Independent and Joint Associations'. *Annals of Epidemiology* 18, 682-695

Slaughter, M. H., Lohman, T. G., Boileau, R. A., Horswill, C. A., Stillman, R. J., Van Loan, M. D., Lopes, V. P., Stodden, D. F., Bianchi, M. M., Maia, J. A. R., and Rodrigues, L. P. (1998) 'Skinfold Equations for Estimation of Body Fatness in Children and Youth.'. *Human Biology* 60, 709-723

Smith, B. K. (2009) *Obesity among Poor Americans: Is Public Assistance the Problem? Tennessee* USA: Vanderbilt University Press

Southall, J. E., Okely, A. D., and Steele, J. R. (2004) 'Actual and Perceived Physical Competence in Overweight and Non-overweight Children'. *Pediatric Exercise Science* 16, 15-24

Steinsbekk, S., Ødegård, R., and Wichstrøm, L. (2011) 'Treatment of Obesity in Children: Parent's Perceived Emotional Barriers as Predictor of Change in Body Fat'. *Obesity Research and Clinical Practice* 5, 229-238

Stodden, D.F., Goodway, J.D., Langendorfer, S.J., Roberton, M.A., Rudisill, M.E. and Garcia, C. (2008) 'A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity: An Emergent Relationship'. *Quest* 60, 290-306

Stratton, G., Fairclough, S. J. and Ridgers, N. D. (2008) 'Physical Activity Levels during the School Day'. In *Youth Physical Activity and Sedentary Behaviour: Challenges and Solutions*, by A. L. Smith and S. J. H. Biddle. Champaign: IL, USA: Human Kinetics 321-350

Strauss, R.S., Rodzilsky, D., Burack, G. and Colin, M. (2001) 'Psychosocial Correlates of Physical Activity in Healthy Children'. *Archives of Pediatrics and Adolescent Medicine* 155, 897-902

Summerbell, C., Waters, E., Edmunds, L., Kelly, S., Brown, T., and Campbell, K. (2005) Interventions for preventing obesity in children. *Cochrane Database of Systematic Reviews* 3, 1-80

Sung, R.Y., Yu, C.W., So, R.C., Lam, P.K. and Hau, K.T. (2005) 'Self-Perception of Physical Competences in Preadolescent Overweight Chinese Children.' *European Journal of Clinical Nutrition* 59, 101-106

Swartz, A. M., and D. L. Thompson. (2003) 'Increasing Daily Walking Improves Glucose Tolerance in Overweight Women. *Preventative Medicine.* 37, 356–362

Talen, M.R. and Mann, M.M. (2009) 'Obesity and Mental Health.' *Primary Care* 36, 287-305

Tammelin,T.H., Nayha, S., Hills, A.P. and Jarvelin, M. R. (2004) 'Adolescent Participation in Sports and Adult Physical Activity'. *American Journal in Preventative Medicine*, 28

The Health and Social Care Information Centre, Lifestyles Statistics (2012) *National Child Measurement, Programme: England, 2011/12 School Year*. London, England: National Obesity Observatory

The Health and Social Care Information Centre, Lifestyles Statistics (2012) *National Child Measurement Programme: England, 2011/12 School Year*. London, England: NHS

Theofili, A. and Simons, J. (2004) 'Comparison of the Results of Children with Psychiatric Disorders on Two Tests Measuring Motor Abilities.' *International Journal of Child and Family Welfare*, 7, 170-180

Thomas, J. R. and French, K. E. (1985) 'Gender Differences Across Age in Motor Performance: A Meta-Analysis'. *Psychological Bulletin* 98, 206-282

Thomasset, A. (1962) 'Bio-electrical properties of tissue impedance measurements'. *Lyon Medical* 207, 107-18.

Thompson, W.R., Gordon, N.F. and Pescatello, L.S. (2009) *ACSM's Guidelines for Exercise Testing and Prescription.* Eighth edn. Baltimore, USA: Lippincott Williams and Wilkins

Trost, S.G., Pate, R.R., Freedson, P.S., Sallis, J.F. and Taylor, W.C. (2000) 'Using Objective Physical Activity Measures with Youth: How Many Days of Monitoring are Needed?' *Medicine and Science in Sports and Exercise* 32, 426-431

Trost, S. G., Ward, S. D., Moorehead, S. M., Watson, P. D., Riner, W., and Burke, J. R. (1998) 'Validity of the Computer Science and Applications (CSA) Activity Monitor in Children.' *Medicine and Science in Sports and Exercise* 30, 629-633

Trost, S.G., Kerr, L.M. and Ward, D.S. (2001) 'Physical Activity and Determinants of Physical Activity in Obese and Non-Obese Children. *International Journal of Obesity*, 25, 822-829

Trost, S. G. (2007) 'State of the Art Reviews: Measurement of Physical Activity in Children and Adolescents'. *American Journal of Lifestyle Medicine,* 1, 299-314

Trudeau, F. and Shephard, R. J. (2005) 'Contribution of School Programmes to Physical Activity Levels and Attitudes in Children and Adults'. *Sports Medicine,* 35, 89-105

Tudor-Locke, C., Williams, J. E., Reis, J. P., and Pluto, D. (2002) 'Utility of Pedometers for Assessing Physical Activity'. *Sports Medicine* 32, 795-808

Tudor-Locke, C., Ham, S.A., Macera, C.A., Ainsworth, B.E., Kirtland, K.A., et al. (2004) *'*Descriptive epidemiology of pedometer-determined physical activity'. *Medicine and Science in Sports Exercise* 36, 1567–1573

Ulrich D. (1984) 'The Reliability of Classification Decisions made with the Objectives-Based Motor Skill Assessment Instrument'. *Adapted Physical Activity Quarterly,* 1, 52-60

University of Hull (2013) *Primary PGCE Programme 5 - 11 Years* [online] available from <http://www2.hull.ac.uk/ifl/ces/courses/pgce/teacher-training-primary.aspx> [02/11/2014]

US Department of Health and Human Services. (2008) *Physical Activity Guidelines for Americans.* [online] available from <http://www.health.gov/paguidelines/.> [03/04/2014]

Valentini, N. and Rudisill, M. (2004) 'Motivational Climate, Motor-Skill Development, and Perceived Competence: Two Studies of Developmentally Delayed Kindergarten Children'. *Journal of Teaching in Physical Education* 23, 216-234

Van Hoomissen, J.D., Chambliss, H.O., Holmes, P.V., Dishman, R.K. (2003) 'The effects of chronic exercise and imipramine on mRNA for BDNF after olfactory bulbectomy in rat'. *Brain Research* 974, 228 –35

Vandaele, B., Cools, W., de Decker, S., and de Martelaer, K. (2011) 'Mastery of Fundamental Movement Skills among 6-Year-Old Flemish Pre-School Children'. *European Physical Education Review* 17, 3-17

Vandorpe, B., Vandendriessche, J., Vaeyens, R., Pion, J., Matthys, S., Lefevre, J., Philippaerts, R., and Lenoir, M. (2012) 'Relationship between Sports Participation and the Level of Motor Coordination in Childhood: A Longitudinal Approach'. *Journal of Science and Medicine in Sport* 15, 220-225

Vaynman, S., Ying, Z., Gomez-Pinilla, F. (2003) 'Interplay between brain-derived neurotrophic factor and signal transduction modulators in the regulation of the effects of exercise on synaptic-plasticity'. *Neuroscience* 122, 647–57

Veitch, J. Bagley, S. Ball, K. and Salmon, J. (2005) 'Where do children usually play? A qualitative study of parents' perceptions of influences on children's active free-play'. *Health and Place* 12, 383-393

Visser, J., Geuze, R. H., and Kalverboer, A. F. (1998) 'The Relationship between Physical Growth, the Level of Activity and the Development of Motor Skills in Adolescence: Differences between Children with DCD and Controls'. *Human Movement Science* 17, 573-608

Warburton, P. and Woods, J. (1996) 'Observation of Children's Physical Activity Levels during Primary School Physical Education Lessons'. *European Journal of Physical Education* 1, 56-65

Wasmund-Bodenstedt, U. (1988) 'High and Low Achievers in Primary School Physical Education'. *International Journal of Physical Education* 15, 13-19

Weiss, M.R. and Amorose, A.J. (2005) 'Children's Self-Perception, in the Physical Domain: Between-and within-Age Variability in Level, Accuracy, and Sources of Perceived Competence'. *Journal of Sport and Exercise Psychology* 27, 244

Weiss, M. R. (2013) 'Back to the Future: Research Trends in Youth Motivation and Physical Activity'. *Pediatric Exercise Science* 25, 561-572

Welk, G.J., Corbin, C.B. and Dale, D. (2000) ' Measurement Issues in the Assessment of Physical Activity in Children'. *Research Quarterly for Exercise and Sport* 71, 59-73

Weltman, A., Janney, C., Rians, C.B., Strand, K., Berg, B., Tippitt, S., Wise, J., Cahill, B.R., Katch, F.I. (1986) 'The effects of hydraulic resistance strength training in pre-pubertal males'. *Medicine Science in Sport and Exercise* 18, 629 - 638

Westendorp, M., Houwen, S., Hartman, E., and Visscher, C. (2011) 'Are Gross Motor Skills and Sports Participation Related in Children with Intellectual Disabilities?' *Research in Developmental Disabilities* 32, 1147-1153

Westerterp, K. R. and Plasqui, G. (2004) 'Physical Activity and Human Energy Expenditure'. *Current Opinion in Clinical Nutrition and Metabolic Care* 7, 607-613

Weyand, P. G., Sternlight, D. B., Bellizzi, M. J., and Wright, S. (2000) 'Faster Top Running Speeds are Achieved with Greater Ground Forces Not More Rapid Leg Movements'. *Journal of Applied Physiology* 89, 1991-1999

Wiart, L. and Darrah, J. (2001) 'Review of Four Tests of Gross Motor Development'. *Developmental Medicine and Child Neurology* 43, 279-285

Wickramasinghe, V. P., Lamabadusuriay, S. P., Cleghorn, G. J. and Davies, P. S. (2008) 'Use of Skin-Fold Thickness in Sri Lankan Children: Comparison of several Prediction Equations'. *The Indian Journal of Pediatrics* 75, 1237-1242

Wilkinson, J. D., Diamond, M., and Miller, T. L. (2011) 'The Promise of Cardiovascular Biomarkers in Assessing Children with Cardiac Disease and in Predicting Cardiovascular Events in Adults'. *Progress in Pediatric Cardiology* 32, 25-34

Williams, G. and Fruhbeck, G. (2009) *Obesity Science to Practice*. Sussex, UK: Wiley -Blackwell

Williams, H. G., Pfeiffer, K. A., O'Neil, J.R., Dowda, M., McIver, K. L. and Brown, W. H. (2008) 'Motor Skill Performance and Physical Activity in Preschool Children'. *Obesity* 16, 1421-1426

Withers, R.T., LaForgia, J., Pillans, R. K., Shipp, N. J., Chatterton, B. E., Schultz, C. G., Leaney, F. (1998) 'Comparisons of two-, three-, and four-compartment models of body composition analysis in men and women'. *Journal of Applied Physiology*. 85, 238-245

World Health Organization (2013) *Obesity and Overweight* [online] available from <http://www.who.int/mediacentre/factsheets/fs311/en/> [10/03/2014]

World Health Organization (2000) *Obesity: Preventing and Managing the Global Epidemic.* Geneva Switzerland: WHO

Wrotniak, B. H., Epstein, L. H., Dorn, J. M., Jones, K. E., and Kondilis, V. A. (2006) 'The Relationship between Motor Proficiency and Physical Activity in Children'. *Pediatrics* 118, 1758-1765

Xu, Q., Anderson, D., and Lurie-Beck, J. (2011) 'The Relationship between Abdominal Obesity and Depression in the General Population: A Systematic Review and Meta-Analysis'. *Obesity Research and Clinical Practice* 5, 267-278

Yarasheski, K.E., Zachwieja, J.J., Bier, D.M. (1993) 'Acute effects of resistance exercise on muscle protein synthesis rate in young and elderly men and women'. *American Journal of Physiology and Endocrinology Metabolism* 265, 210-214

Yu, F. Y. and Lui, Y. H. (2009) 'Creating a Psychologically Safe Online Space for a Student-Generated Questions Learning Activity Via Different Identity Revelation Modes. *British Journal of Educational Technology*, 40, 1109–1123

Zakarian, J.M., Hovell, M.F., Hofstetter, C.R., Sallis, J.F. and Keating, K.J. (1994) 'Correlates of vigorous exercise in a predominantly low SES and minority high school population'. *Preventative Medicine* 23, 14-321.

Zaninotto, P., Wardle, H., Stamatakis, E., Mindell, J., and Head, J. (2006) 'Forecasting Obesity in 2010'. *Department of Health, National Centre for Social Research,* London, UK: DoH

Ziviani, J., Poulsen, A., and Hansen, C. (2009) 'Movement Skills Proficiency and Physical Activity: A Case for Engaging and Coaching for Health (EACH)-Child'. *Australian Occupational Therapy Journal* 56, 259-265

# 11.0 Appendices

## Appendix I: Ethics approval

# Appendix I: Invite letter to schools for the intervention.

Dear (School name)

We would like to invite your school to take part in a research project run by Coventry University. The project will involve a physical activity intervention with the aim to increase children's Fundamental Movement Skill (FMS) Levels. For the past two years I have assessed the FMS levels in children at Coundon Primary school and found that children's FMS levels are far below what they should be and physical activity guidelines are not being met!!

For our research projects we work closely with the Ken Adamson Education and Learning Consultant for PE at Coventry Education Service. He has recommended your school to participate in the research project.

We would welcome the opportunity to discuss the project with you further and the benefits of taking part in the project for your school.

We can be contacted at the following address:

Miss Lizi Bryant            e-mail: bryante2@uni.coventry.ac.uk

Dr Samantha Birch          e-mail: samantha.birch@coventry.ac.uk

We look forward to hearing from you with the possibility of working with you in the near future.

Yours Faithfully

Lizi Bryant

## Appendix II: Sample informed consent.

Dear Parent/Guardian,

For the past three years the Department of Biomolecular and Sport Science at Coventry University in partnership with Coventry Education Service have been conducting a research study assessing factors affecting physical activity in primary and secondary school children in Coventry. Both Coundon Primary School and Coundon Court Secondary School have again kindly agreed to be involved in this on-going research therefore, we would like to ask permission for your child to participate once again. The majority of children at Coundon Primary will have already participated previously in this work.

The children involved in the study would be asked to complete 8 Fundamental Movement Skills (FMS) during their PE lessons. These skills include: Static balance, sprint run, vertical jump, kick, hop, catch, overhand throw and a side gallop. All of these are the under pinning skills in sporting activities. These FMS are no more strenuous than what is usually carried out as part of a normal Physical Education lesson. Physical activity levels will also be measured at home and school using a 4 day pedometer step count. Other measurements such as height, weight, body composition and heart rate will also be assessed in their PE lesson. All these measurements were carried out in January 2013 and we are writing to you again for permission to repeat the same tests in January 2014.

All the procedures used are safe, will be conducted by trained personnel and do not require you/your child to do anything extra in your day to day routine. The data will be anonymous, treated in confidence and solely used for the purposes of the research study. Participation in the study is entirely voluntary and you/your child have the right to withdraw from the study at any time. Participation in this project will help our scientific understanding of the influences that contribute to the mastery of FMS. We hope you will be interested in allowing your child to participate in this project once more and should you have any queries please do not hesitate to get in touch.

Yours Sincerely

Elizabeth S Bryant

Principle investigator

PhD Student, Coventry University

I give permission for my son/daughter _____ (insert name)

Class_____ to participate in the above mentioned study. I understand that the data will remain anonymous and will only be used for the purposes described above, that I have the right to withdraw at any time and that participation is entirely voluntary.

Signed: _____ (Parent/Guardian) _____ (Date)

**Other information you may find useful**

**What the study involves**

The children involved in the study would be asked to complete 8 Fundamental Movement Skills (FMS). These skills include: Static balance, sprint run, vertical jump, kick, hop, catch, overhand throw and a side gallop. The skills will be filmed with a video camera for analysis, and will be destroyed at the end of the project. All of these are the under pinning skills in sporting activities. Physical activity will be measured using a 4 day pedometer step count reading. Other measurements will be height, weight, heart rate and body composition.

**Withdrawal**

If at any time during the testing your child would like to withdraw (or you would like to withdraw them), you are free to do so without any recourse.

**What are the benefits?**

It cannot be guaranteed that the study will benefit you/your child directly but the information will increase our knowledge on how mastery of FMS is influenced by different factors. Recent research has suggested that there is an association between mastery of FMS and participation in physical activity. Therefore a greater understanding of this relationship could give schools the knowledge on how to maximise this and increase physical activity and reduce disease risk in the future.

**What are the risks?**

The risks that your child may encounter during the testing are minimal and no more than encountered during their day to day physical activities.

**What happens to the information?**

Procedures for handling, processing, storage and destruction of their data match the Caldicott principles and the Data Protection Act 1998. All data gathered will be anonymous and treated in strictest confidence. It will only be used for the purposes described above and only the principal researcher will have access to the data.

**Who has reviewed this study?**

This study has been reviewed and approved by the Ethics Committee at Coventry University and the procedures in place in the study adhere to the Code of Conduct of the British Association of Sport and Exercise Sciences

**What if I have more questions?**

If you have any further questions please get in touch with the principal researcher for the study, Elizabeth Bryant, Telephone:07814186168 or e-mail bryante2@coventry.ac.uk

Or Dr Samantha Birch or Dr Michael Duncan (The project Supervisor) at Department of Biomolecular and Sports Sciences, James Starely Building, Coventry, CV1 5FB, Telephone: 02476 888559/ 02475 888613 or e-mail: s.birch@coventry.ac.uk/ michael.duncan@coventry.ac.uk

Further relevant information can also be gained from the British Association of Sport and Exercise Sciences on their website www.bases.org.uk should you feel that your child's participation in the study has raised any issues.

Supported by

# Appendix III: Process Orient Checklist

| Skill Year(s) tested | Description | Components | |
|---|---|---|---|
| Static balance 3 | Stand and balance on one leg | 1 | Support leg still, foot flat on ground |
| | | 2 | Non support leg bent, not touching support leg |
| | | 3 | Head stable eyes focussed forward |
| | | 4 | Trunk stable and upright |
| | | 5 | No excessive arm movements |
| Sprint run 3 | Run as fast as possible between two points 20 metres apart | 1 | Land on ball of foot |
| | | 2 | Non-support foot bent at least 90° in recovery |
| | | 3 | High knee lift, thigh parallel to ground |
| | | 4 | Head and trunk stable eyes forward |
| | | 5 | Elbows bent at 90° |
| | | 6 | Arms drive forward and back, opposite legs |
| Vertical jump 3 and 4 | Jump up vertically as high as possible from knees-bent standing position | 1 | Eyes focussed forward or upward throughout |
| | | 2 | Crouch with knees bent. Arms behind the body |
| | | 3 | Forceful forward and upward swing of arms |
| | | 4 | Legs straighten in air |
| | | 5 | Land on balls of feet. Bend knees to absorb land |
| | | 6 | Controlled landing with $< = 1$ step any direction |
| Kick 3 and 4 | Run up to and kick a 20cm playground ball as far as possible with top of foot | 1 | Eyes focussed on the ball throughout |
| | | 2 | Forward and sideways swing of opposite arm |
| | | 3 | Non kicking foot placed beside ball |
| | | 4 | Bend knee of kick leg 90°+ during backswing |
| | | 5 | Contact ball with top of foot |
| | | 6 | Kick leg follows through high towards target area |
| Hop 3 and 4 | Hop between two points 15 metres apart | 1 | Support leg bent landing then straight to push up |
| | | 2 | Push off and land on ball of foot |
| | | 3 | Nonsupport leg bent and swings with other leg |
| | | 4 | Head stable and eyes focussed forward |
| | | 5 | Arms bent and swing forward as support leg pushes off |
| Catch 3 and 4 | Catch a soft ball thrown underarm from 3-5 metres distance to 2 metres high | 1 | Eyes focussed on the object throughout |
| | | 2 | Feet move to place body in line with object |
| | | 3 | Hands move to meet the object |
| | | 4 | Hands and fingers relaxed and slightly cupped |
| | | 5 | Catch/control object with hands only. Well timed closure |
| | | 6 | Elbows bend to absorb force of object |
| Overhand throw 4 | Throw a soft ball overarm as far as possible | 1 | Eyes focussed on target area throughout |
| | | 2 | Stand side on to target |
| | | 3 | Throwing arm in downward and backward arc |
| | | 4 | Step towards target area with foot opposite throwing arm |
| | | 5 | Hips then shoulders rotate forwards |
| | | 6 | Throw arm follows through down and across body |
| Side gallop 4 | Gallop sideways between two points 15 metres apart | 1 | Smooth rhythmical movement |
| | | 2 | Brief period where both feet are on the ground |
| | | 3 | Weight on the balls of the feet |
| | | 4 | Hips and shoulders point to the front |
| | | 5 | Head stable, eyes focussed forward or in direction of travel |

**Appendix IV: Pedometer data collection sheet.**

# Pedometers!!

| Day | Step Counts and other information |
|---|---|
| Friday | |
| Saturday | |
| Sunday | |
| Monday | |

Number:                                                     Pedometer
Number:

## Instructions!

- Wake up and press the yellow button to reset to 0.
- Attach it to your clothes (trousers, skirt, leggings, shorts) on the hip.
- Wear all day and put it on every change of clothes you wear and for every activity you do.
- If you complete an activity that you are unable to wear the pedometer. Write what activity you participated in and how long for.
- Do NOT get it wet, Do NOT wear it swimming or in the shower!!
- At the end of the day before bed, open the pedometer and record the number in to the record table above.
- Repeat this process Friday, Saturday Sunday and Monday.
- On Tuesday please hand the pedometer and the record sheet in to your teacher.

Have fun using the pedometer and thank you for your help! ☺

**Appendix V: The Perceived Physical Competence Subscale for Children (PPCSC), (Harter, 1982).**

Initial Modification to Harter's PPCSC

## Physical Education Efficacy Scale

| Circle one: Boy or Girl |
|---|

**1.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty performing cartwheels | but | Other kids can perform cartwheels easily | ____ | ____ |

**2.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty performing gymnastics. | but | Other kids can perform gymnastics easily. | ____ | ____ |

**3.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty doing the mile run. | but | Other kids can do the mile run easily. | ____ | ____ |

**4.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty doing pull-ups. | but | Other kids can do pull-ups easily. | ____ | ____ |

**5.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty dancing. | but | Other kids can dance easily | ____ | ____ |

**6.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty performing sit-ups. | but | Other kids can perform sit-ups easily. | ____ | ____ |

**7.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty shooting a basketball. | but | Other kids can shoot a basketball____ easily. | ____ | ____ |

**8.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty shooting baskets from the free-throw line. | but | Other kids can shoot baskets from the free-throw line easily. | ____ | ____ |

**9.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty foot dribbling a soccer ball. | but | Other kids can foot dribble a soccer ball easily. | ____ | ____ |

**10.**

| Really true for me | Sort of true for me | | | | Sort of true for me | Really true for me |
|---|---|---|---|---|---|---|
| ____ | ____ | Some kids often have difficulty playing tag games. | but | Other kids can play tag games easily. | ____ | ____ |

**Appendix VI: Pictures from the six week intervention weeks 3-6 circuits (Chapter 6).**

**Station 1: Hopping**



Hopping over agility hurdles at the lowest height

**Station 2: Kicking**



Kicking a ball at the yellow stars on the wall.

**Station 3: Throwing**



Throwing at the coloured hands on the wall.

**Station 4: Jumping**



Jumping on the trampet.

**Station 5: Balance**



Walking along a bench to improve balance.